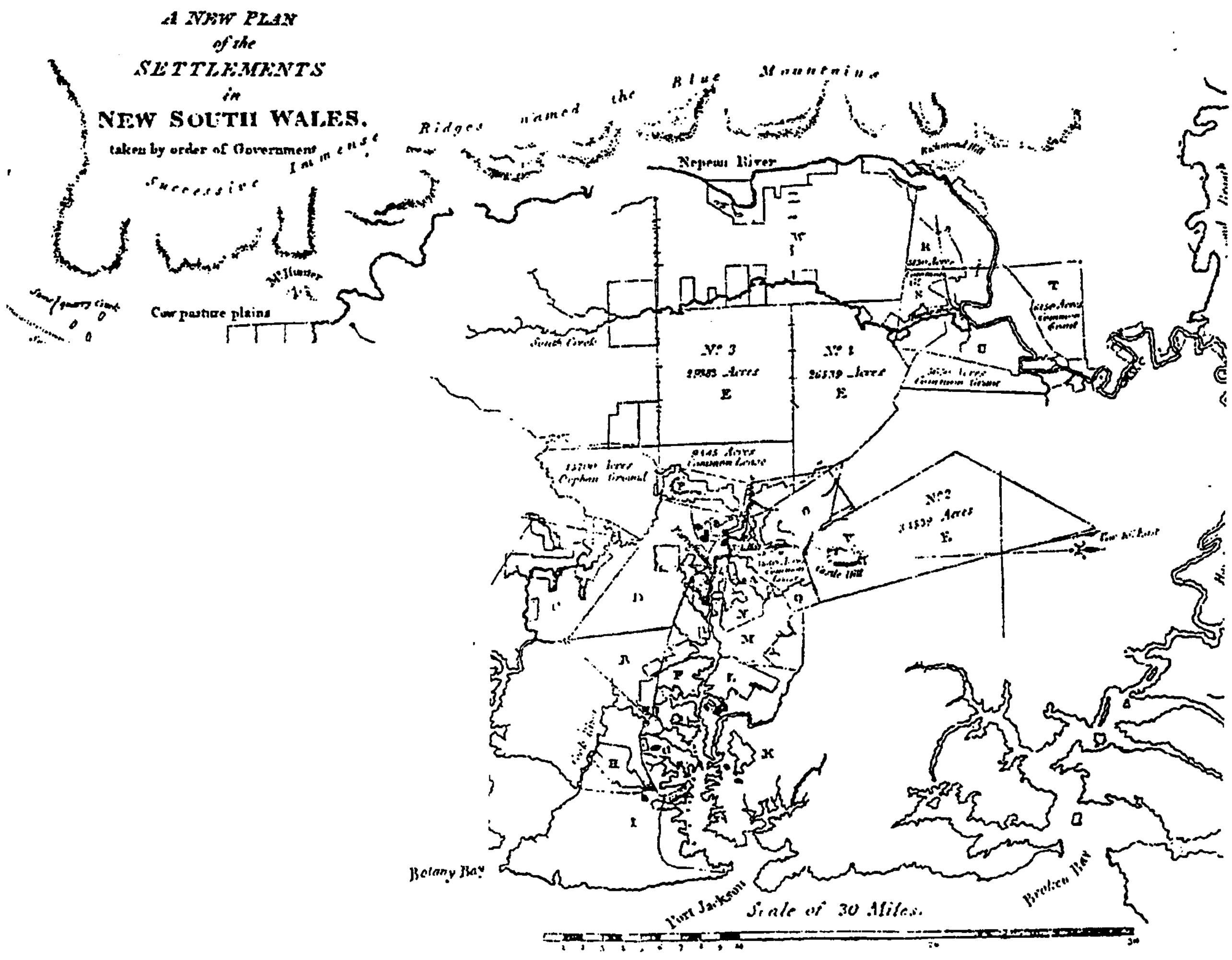
THE NATURE AND MANAGEMENT OF POSITIONAL RELATIONSHIPS WITHIN A LOCAL GOVERNMENT GEOGRAPHIC INFORMATION SYSTEM

DAVID B. LEMON



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ABSTRACT

The increasing use of Geographical Information Systems (GIS) has prompted some people to look at the way in which positional information is managed. Whilst there are a number of methods for storing and representing spatial information, very few commercial GIS packages allow for the maintenance of the relationship information (named 'positional relationships') used in the initial data capture process. Furthermore, in many cases the method for storing spatial information is quite different to the way in which it was acquired, and in some cases, not conducive to the purposes for which it was originally collected.

A 'positional relationship' is defined as being:

> *Any relationship between spatial features which has been used, primarily, to determine the real world position of one of those features with respect to the other features, during initial data capture.*

One area of the GIS community which depends heavily upon positional relationships is local government. Local government is a large user of GIS technology and uses many different spatial data sets to carry out its functions. It is in the unique position of being both a land and environment management organisation as well as a provider of many services to the community. Much of the data used by local governments however, are collected or created using positional relationships to other spatial features. These relationships between features in different data sets are, in some cases, very important.

One of the most common data sets used by local government is the cadastre. Unfortunately, the cadastre is a dynamic data set. That is, features in this data set are undergoing constant change. This change occurs for one of two reasons. Firstly, new information about the original position of a feature may have been acquired resulting in the position of the feature being upgraded. Secondly, the feature has moved in reality and information about the new position of the feature has been obtained. This is known as an update.

Unfortunately little is understood of the effect these positional changes have upon any positional relationships a changed feature is involved in. It is understood that in certain circumstances, it will be necessary to maintain the relationship. That is, adjust the position of the related feature. It is not understood what factors affect such situations.

The purpose of this study therefore was to investigate the nature of the positional relationships used in a local government geographic information system. Using the results of this investigation, a set of requirements for a system to manage these relationships is developed.

In order to carry out this task a number of steps were undertaken.

Firstly it was necessary to determine exactly what types of spatial information are being collected and used by local governments. This was done by investigating the statutory requirements of local government in the state of New South Wales and by surveying a number of councils, asking what GIS data sets they use and how the data are collected or created.

Secondly an investigation into the positional relationships between features in each of these data sets was undertaken. In particular, this study looked at which types of spatial features are related, how they are related and why they are related. A set of fundamental types of positional relationships was then developed. Furthermore, it was necessary to develop a technique for categorising a relationship (called a relationship's 'class') based upon the purpose for which that particular relationship exists.

The next step involved investigating the different types of positional changes that occur within spatial databases. It was necessary to look at, not only how and when these changes occur, but also their effect upon different positional relationships. It was then possible to develop rules for managing positional relationships in a GIS as well as a set of criteria for the management of positional relationships in a local government GIS.

The original contribution of this study has therefore been:

- an investigation of the spatial information used by local governments in New South Wales;
- an investigation of the nature and use of positional relationships in the GIS industry;
- the development of a list of fundamental positional relationships which can be used singularly or in combination to describe any positional relationship.

- the development of a method for categorising positional relationships based upon the purpose for which the relationship exists.
- an investigation of the process of positional change in a spatial database and effects these changes have upon different types of positional relationship;
- a rules base for the management of positional relationships in a local government GIS; and
- a discussion of the issues involved in the management of positional relationships.

The results of this study can be used to develop a set of techniques for the comprehensive management of positional relationships in any local government geographic information system.

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For my father

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GLOSSARY

AMG The Australian Map Grid. A Transverse Mercator mapping grid based upon the Australian Geodetic Datum 1966, used throughout Australia.

DCDB Digital Cadastral DataBase. A spatial database representing cadastral information.

DCP Development Control Plan. A plan, developed and used by individual local governments in New South Wales for controlling development.

GIS Geographic Information System

ISG The Integrated Survey Grid of New South Wales. Another Transverse Mercator mapping grid used only in NSW

LIC Land Information Centre. A NSW government authority responsible for the capture and maintenance of various spatial data sets

LIS Land Information System.

NSW New South Wales. The most populous state of Australia.

WGS84 World Geodetic System 1984. A world based geodetic datum.

1. INTRODUCTION

1.1 Organising Spatial Information

There are many ways to arrange spatial information (Laurini and Thompson, 1992, p6.), a number of which are used to organise data in Geographic Information Systems (GIS). Bernhardsen (1992) points out that data in most GIS are organised into layers, or levels. In general, each layer is used to represent data of a common theme. For example, property boundaries may be represented in one layer and natural drainage features another. A layer can contain raster information, where the layer is divided into regularly sized cells, or it can contain vector data, where individual features in the real world, are represented by point, line or polygon features in the GIS (Burrough 1986, Bernhardsen 1992, Laurini and Thompson 1992).

Another popular method for organising spatial data uses the principles of object-orientation. Rather than dividing the world into a series of points, lines and polygons on separate layers, object-oriented systems represent each real world feature by an object (Maguire, 1994). Each object can be regarded as an 'information packet' containing data about the feature it represents. This data might include the feature's name and position. All objects are instances of a class (Hesse, 1991). Objects belonging to the same class display common properties. These properties define such things as how each object in the class is to be displayed.

Whilst the above methods for arranging spatial data are different, they have one thing in common. They use some form of cartesian coordinates to represent the position of the feature in the real world. These coordinates can be associated with individual features in different ways. For example, they may be inferred from the grid cell position in a raster GIS, or in vector and object-oriented systems, they might be defined with respect to a predetermined mapping datum. In each of these cases however, the positional information stored is the position of the feature with respect to some datum. That is, assuming that the position of the datum with respect to the real world is known, the absolute position of the feature is stored.

For those who use spatial information however, it is quite often the case that the relationships between different features will be of greater importance than the absolute position of individual features. Examples of this can be found throughout the spatial information industry. Three examples are:

1. The cadastral surveyor measures the distance between a boundary line and the wall of a building to determine compliance with various regulations.

2. The planning engineer uses the distance between a cadastral boundary and existing water pipes to determine where to place a new powerline.

3. The maintenance engineer needs to know where the buried sewer entrance is with respect to a fenceline in order to find it and carry out upgrading work.

In each of these cases, the positions of the individual features with respect to some mapping datum are of less importance than the position of one feature with respect to the other.

Furthermore, as part of the process of creating spatial data sets, it is necessary to determine the real world positions of the features to be mapped. There are many methods for performing this task, however it is quite often the case that the processes used will involve the use of relationships to nearby features. For example:

- The location of a stormwater pit might be determined using measurements to nearby fence corners.
- A suburb boundary might be defined as being in the same position as the centreline of a road corridor.
- Areas at risk of being affected by particular flood events are determined using drainage and contour information in the area.

The increasing use of GIS for the storage and manipulation of spatial information has prompted some people to look at the way in which the positional component of spatial information is managed. It has been recognised that whilst current methods for storing and representing this information are both efficient and allow for ease of manipulation, they do not represent the way in which the data was collected or created.

In a perfect world this would not be a cause for concern. The real world positions of all features would be known to an accuracy far greater than that required by the user. Furthermore, these positions would not change for the life of the data set. Hence, there would be no need to make changes to the positions of these features, as represented within the spatial database, due to the acquisition of more accurate information or changes to the real world features. As a result, relationships between features could, at all times, confidently be determined using Cartesian geometry. That is, these relationships could be determined from their coordinates.

However, the world is less than perfect. Data capture is performed at accuracies determined as much by economics as by user requirements, and changes to the features represented within spatial databases are occurring constantly. Therefore, the need to make positional changes to spatial information already captured is quite real.

1.1.1 The Problem

However, a problem occurs, as the act of making these changes may compromise relationships used in the original data capture process. That is, by changing the position of a feature within a spatial database, the positions of other features, which have been positioned purely by the use of relationships to that feature, may require a similar change. For example, if an electoral boundary is defined as being coincident with a particular cadastral boundary, a relationship exists between the two features. That is, they have the same position. As a result, immediately after initial data capture, the positions of the two features, as represented in the spatial database, will be the same. If however, it is necessary at a later time to change the position of the cadastral boundary, it may also be necessary to change the position of the electoral boundary. Unfortunately, as no information about the relationship between the positions of the two features is stored within the GIS, such a change will be difficult to achieve.

It can be seen that, as more changes are made to the spatial data, the confidence with which the relationships between features can be determined, using Cartesian geometry, will be severely degraded.

1.2 Positional Relationships

The existence of these relationships has been recognised by a number of authors (Kjerne and Dueker 1986, Corson-Rikert 1988, Driessen and Zwart 1989, Hebblethwaite 1989). They have been referred to as 'associativity' (Hesse 1991, Wan 1993, Baker and Paxton 1994), 'relativity' (Hadjiraftis and Jones 1991, O'Dempsey and Moorhead 1991), 'graphical data dependencies' (Unkles 1992) and 'vertical topology' (Blackburn 1994). For this thesis, the term 'positional relationship' will be used. This term has been used as it is felt that, unlike previous terms, it helps to describe the nature of these relationships. That is, they are *relationships* between the *positions* of the spatial features.

A positional relationship is defined as:

> *Any relationship between spatial features which has been used, primarily, to determine the real world position of one of those features with respect to the other features, during initial data capture.*

For example, if, in order to determine the position of a sewer entrance, physical measurements are made to nearby fence corners, then positional relationships exist between the entrance and each of these corners. Further, if a particular administrative boundary (eg. an electoral boundary) is defined as being coincident with some other boundary (eg. a Local Government Boundary), then a positional relationship exists between these two boundaries.

1.3 The Research Purpose

Whilst the existence of positional relationships has been acknowledged and the need to maintain them is widely accepted, little is understood about the nature of these relationships. That is, there has been very little investigation into the types of positional relationships used, the different ways in which they are used and the effect upon them of the different types of positional changes that can occur in spatial databases. To the present, the majority of research has concentrated upon techniques for maintaining relationships after the occurrence of one particular form of positional change. There has been little obvious work done to determine whether maintenance of a relationship is, in fact, the correct action to take for all cases of a positional change. That is, there may be instances where maintenance of a relationship will actually degrade the spatial database. In such situations a different action might be required with respect to the features involved in the positional relationship.

The purpose of this research, therefore, is to investigate the nature of positional relationships. Specifically, the investigation will look at those aspects of a positional relationship that determine how the relationship will be affected by positional changes to the features involved. The findings of this investigation will then be used to develop a set of rules that can be used to comprehensively manage positional relationships in a working GIS. This rules base will allow users to determine the required action to take with respect to the features involved in a positional relationship should this relationship be affected by a positional change.

Note: The terms 'manage' and 'maintain' will be used with respect to positional relationships throughout this thesis. It is therefore important to understand the difference between them. In order to **manage** a relationship it is necessary to determine what action is required with respect to that relationship and then perform it. This action may take a number of forms. The process of **maintaining** a positional relationship however, involves repositioning spatial features such that they are in their correct positions relative to the other features involved in the relationship.

1.4 The Research Focus

One area of the community which depends heavily upon the use of spatial information is local government. As a result, local government bodies, (sometimes referred to as councils) are a large user of GIS technology. Furthermore, they are in the unique position of being both a land and environment management organisation as well as a provider of many services to communities. Thus, they have the potential to use many different types of spatial data.

With this in mind, it would appear that local government would be a perfect subject for studying the use of positional relationships. Confirmation of this theory comes when it is realised that many of the functions carried out by local government have some relationship with the cadastre. As such, many councils find it necessary to use cadastral information as a base to which features in other data sets are related. Thus these councils will depend quite heavily upon the use of positional relationships in the data capture process.

Given that local governments use positional relationships as a tool for data capture, this thesis will concentrate upon this particular area of the GIS community. However, as councils use a great variety of data sets, the results of this investigation will be able to be applied to other areas of GIS usage.

1.5 Overview of Research and Thesis

As with any investigation of this type, it is first necessary to review the research already documented. It was mentioned earlier that previous research into positional relationships has concentrated upon the development of methods for maintaining them. The review, given in **Chapter 2**, will therefore investigate a number of methods proposed for this purpose.

In order to carry out a thorough investigation into the positional relationships used by local government, it is first necessary to have knowledge of the types of positional relationships used. However this knowledge can only be gained with an understanding of the spatial data used. Hence **Chapter 3** will introduce and discuss an investigation into the spatial data sets used by local governments in the state of New South Wales.

This investigation involves 3 steps. Firstly, the legislative requirements of local government in New South Wales are reviewed. This review will give an insight into the functions and services of local government requiring spatial data. Secondly, a survey of the spatial data maintained by a number of councils is introduced. Amongst other things, this survey asked each council to list the data sets they used within their GIS. Finally a summary of all spatial data sets identified as being used by local government will be given.

Once the data sets used by local government have been identified, it is necessary to look at the positional relationships used to create these data sets. This investigation is detailed in **Chapter 4**.

Chapter 4 starts by investigating the positional relationships used in a number of fields of GIS usage as well as those catered for by 2 commercial GIS packages. Secondly, the positional relationships used to create local government data sets are discussed. Finally, a new classification for positional relationships is developed as well as formal definition for each of the positional relationships identified.

One of the reasons for the need for this research, is that positional changes to features in a GIS will have an effect upon positional relationships. Thus, **Chapter 5** investigates the processes of making a positional change in a local government GIS. Specifically the factors which determine the effect of this change upon a positional relationship are investigated.

Chapter 6 uses the results of the investigations in Chapters 3-5 and develops a set of requirements for managing positional relationships in a local government GIS. This will include a set of rules governing when a relationship should be maintained and when it should not. It will also contain a discussion of some of the issues involved in the management of positional relationships. This chapter will conclude the work for this research.

2. TECHNIQUES FOR MAINTAINING POSITIONAL RELATIONSHIPS

2.1 Introduction

Whilst the need to be able to **manage** positional relationships is important to many users of GIS, the most vocal of these users, over recent times, have been those in the utility industry. In fact the importance of these relationships to this industry is such that problems associated with their maintenance instigated the calling of a forum in Sydney, Australia, to discuss possible solutions (LIC, 1994(c)).

The main subjects of discussion for this forum revolved around the use of the New South Wales (NSW) Land Information Centre's (LIC) Digital Cadastral DataBase (DCDB). This data set is a graphical representation of all cadastral parcels in NSW and is used by a number of utility organisations as a base against which they map their other spatial information. It will be discussed in detail in Section 3.5.

One of the issues raised with respect to the DCDB was that its spatial accuracy was such that it limited the uses to which it could be put. An improvement, or 'upgrade', in this accuracy would therefore greatly enhance its usefulness, especially for engineering purposes. It was recognised, however, that such an upgrade would have the effect of compromising positional relationships which had been used to capture existing utility information.

As a solution to this problem, a number of possible methods to **maintain** positional relationships were proposed. However, these proposals involved little discussion of the types of positional relationships used by the utility industry or of the factors determining the need to maintain a relationship.

In fact the majority of research associated with positional relationships has involved the development of techniques to maintain relationships in cases where underlying base data sets (such as the DCDB) undergo upgrades. Very little effort has been directed at the comprehensive management of all relationships in all cases of a positional change. As a result, whilst a number of techniques for maintaining relationships have been developed, little is understood about the situations which lead to the need to use them.

The purpose of this chapter is to review a number of the techniques which have been proposed for the maintenance of positional relationships. This review will have two purposes. Firstly, it will act as an introduction to the bulk of previous research into such relationships. Secondly, whilst the maintenance of a relationship may only be part of the process of managing that relationship, it is a very important part. It is thus necessary to understand the processes involved in each technique in order to determine which of them is the most appropriate in the local government case.

2.2 Maintaining Positional Relationships

The obvious way to maintain a positional relationship is to perform the task manually. Wan and Williamson (1994a), whilst researching the use of positional relationships, discovered that the only organisation, of a number of Victorian and NSW utility companies, with the ability to maintain positional relationships was the Sydney Water Board (now Sydney Water). The Water Board used a process of deriving relationships from existing graphics and then reapplying these relationships manually after features in the cadastral base data set had undergone a positional change.

It is important to note, however, that in this particular case, the Water Board has a number of inherent advantages in the management of their data. Firstly, they are the custodian of all the spatial information they use and this information is accurate enough for their needs. Thus, they do not depend upon an outside authority to supply their spatial information and there is little likelihood of it undergoing wholesale upgrading to improve data accuracy.

Secondly, their area of operations (greater metropolitan Sydney, the Illawarra and the Blue Mountains regions) is an area of relatively small amounts of cadastral change after initial development. That is, once an area has been initially developed, there is little chance of further large scale development occurring after the Water Board has collected cadastral and network data for that area. Thus the number of further changes to the cadastral data set will be relatively small.

For those organisations who are not the custodians of the data they use and for whom the decision to upgrade is out of their control, a manual method, such as that used by the Water Board is not appropriate. Such a method is time consuming and, due to the potential of human errors occurring, involves a certain element of danger with respect to the quality of the final product. Therefore another approach is required.

Hebblethwaite (1989) recognised the fact that the cadastral models used by mapping organisations were dynamic for many reasons. He identified three different methods for maintaining positional relationships between the cadastre and other mapping layers in the case of an upgrade only. These methods are:

1. the Transformation Method;
2. the Database Method; and
3. Object-Orientation.

For this thesis, Hebblethwaite's three models will be used to head the three categories of techniques proposed for maintaining positional relationships. This categorisation has been used previously when discussing possible solutions (Wan 1993, Wan and Williamson 1994b).

The following sections contain a description of the principles of each of the above methods. Accompanying these descriptions will be examples of the implementation of each method along with previously identified advantages and disadvantages. The following sections will not, however, review each method in the context of applying it to the local government case. Such a review will be given in Chapter 6.

2.2.1 The Transformation Method

The basic principle of Hebblethwaite's transformation method is to apply the same transformation to related features as has occurred to the base features. This is done by introducing control points, into the related data set, which have been derived from the original base data. These control points are then used to transform the related data set such that the introduced control points are coincident with their positions in the new, upgraded base. This process is illustrated in Figure 2.1.

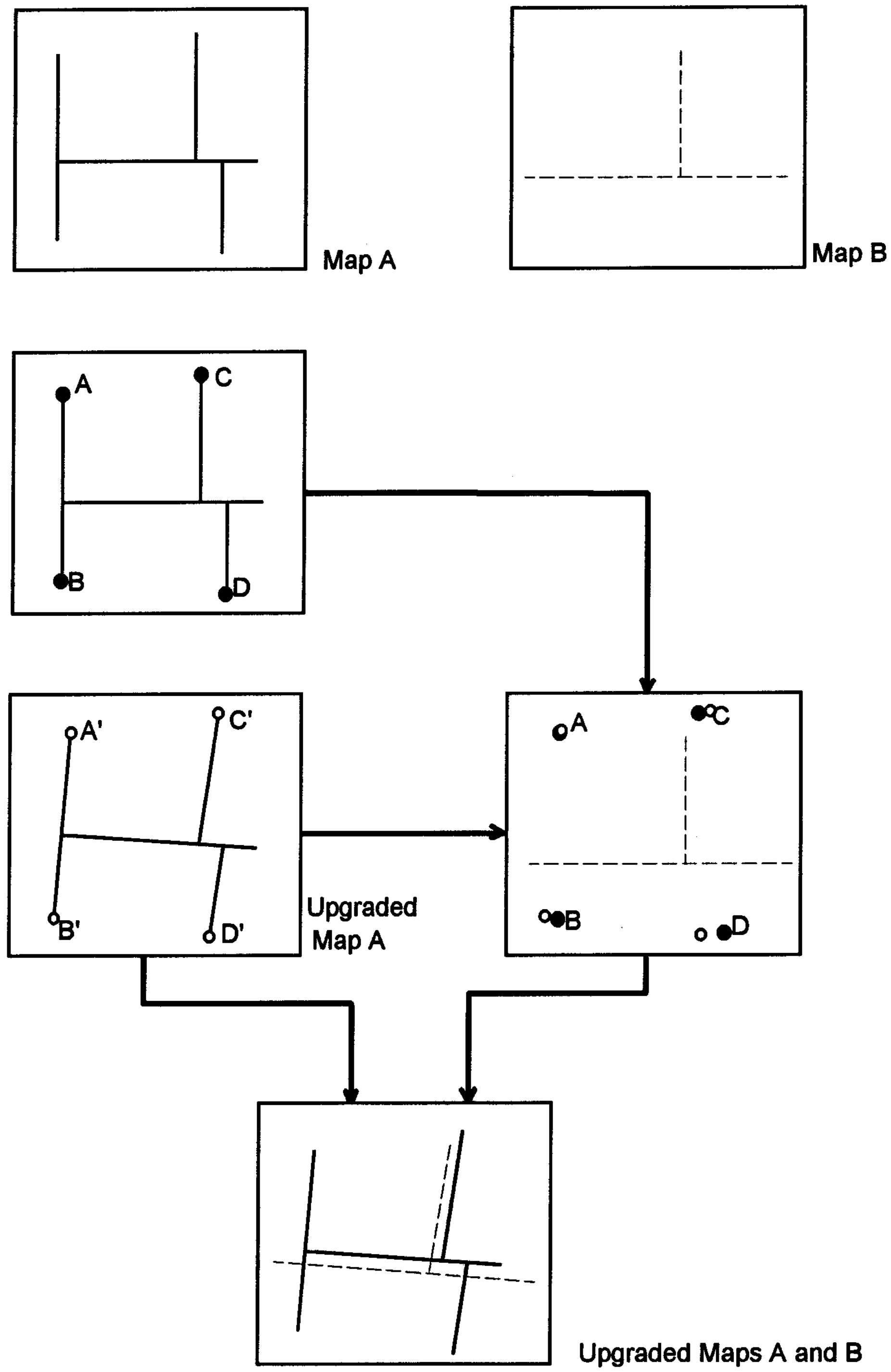


Figure 2.1 The Transformation Method. Map A, which is used as a base for Map B, undergoes an upgrade. In order to perform the same upgrade on Map B, known points from the original Map A (A, B, C, D) are placed into Map B. All features in Map B are then transformed such that the control points align with their positions in the upgraded Map A (A', B', C', and D').

This process does not maintain specific relationships as such. Rather, it attempts, through the transformation, to maintain all features in all data sets in the same relative positions. This is a subtle, yet important difference as it means that specific positional relationships, such as physical measurements, will not be maintained. In fact, in situations where such relationships are used, the transformation process may actually destroy the positional information derived from a relationship, as this information is not specifically stored.

The transformation method, by definition, relies upon the base data undergoing some form of transformation. As such, a number of authors have integrated it into tools for the upgrading of spatial data (Clatworthy 1992b, 1994a, b). These tools use ties, or relationships, to known points (eg. Survey Control Points) to adjust a data set which itself contains all information from all data sets within the GIS. That is, the spatial information from all data sets is placed into one "super" data set and the transformation applied to this one set. After the adjustment the individual data sets are extracted from the "super" set.

In some cases, these tools actually calculate relationships between features of one data set and nearby features in the base data. These relationships are then transformed rather than the actual features. The features are then shifted, according to the transformed relationships, after the upgrade process has taken place. This process is used to overcome certain problems with maintaining point features within polygons.

Integrated upgrading and transformation tools can also use information from data sets other than the base as control for the upgrading process. Thus, for example, if the positions of features in a particular utility data set have been determined to an accuracy greater than that of the data set to be upgraded, these positions can be used as control for the transformation.

Of course, whilst the transformation method is very much dependant upon the upgrading process, it is not necessary that the two be integrated. However, if they are to be independent, it is important that, during the upgrade process, the transformation parameters used are stored. These parameters are necessary for applying a similar transformation to the related data sets.

It should be remembered that Hebblethwaite's methods for maintaining positional relationships where developed with the process of wholesale upgrading of cadastral data sets in mind. Such upgrades will, in general, consist of some form of transformation being applied to the cadastral data. A problem occurs therefore, in situations where a positional change has not involved the use of a transformation. In such situations there are no transformation parameters to apply to the related data sets. The transformation method can not manage positional relationships in such cases.

Due to the shortcomings of this method, very few people have actually considered, or even studied it, as a possible solution for managing positional relationships. There are however two examples of note. The first is an implementation of this approach which has been suggested by Clatworthy (1992a, 1994a, b). The basis of this implementation was discussed previously and involves the creation of a 'super' data set as part of the process of upgrading.

The second exception comes in the form of a study into the use of different types of transformations for relationship maintenance. This study, conducted by Hadjiraftis and Jones (1991), tested Helmert, Affine, Projective and a Second Order Polynomial transformation.

The authors suggest that these types of transformations are designed for situations where the differences between the two data sets are dominated by systematic factors such as shifts, rotations and scale differences. As a result, they cannot be confidently used in situations where local distortions predominate the differences between the data sets. Unfortunately, such local distortions will quite often occur between an upgraded cadastral network and any related spatial data. Hadjiraftis and Jones suggest that these local distortions are 'more likely to be reflected in the post-transformation residuals than be absorbed by the transformation parameters.' That is, such distortions are likely to have an adverse effect upon the accuracy of the positions resulting from the transformation.

As a result of this study, Hadjiraftis and Jones concluded that 'the Transformation Approach is generally unsuitable for [maintaining positional relationships] in large spatial data sets'.

2.2.2 The Database Method

The database method uses information about a positional relationship, stored in a database table, to aid in the maintenance of that relationship. This table is interrogated every time the position of a feature within the GIS undergoes a change. The results of this interrogation will reveal any positional relationships involving the affected feature. For each of these relationships, other stored information can be used to maintain the position of the related feature. Thus, as information about specific relationships is stored, this method can truly maintain a positional relationship.

It would seem, therefore, that the database approach is an almost perfect solution to maintaining positional relationships. There are, however, some major drawbacks, which should be pointed out.

The first difficulty with this method is that the table of relationship information will, for a number of reasons, be dynamic. That is, throughout the life of the GIS, as various features undergo positional changes, positional relationships will be created and destroyed. As a result, if the table of relationship information is to reflect the current state of all positional relationships, it will require constant maintenance similar to that required for maintaining the currency of the spatial data.

Another major complication is that, in order to use this method, it is necessary to be able to uniquely identify those spatial features which are involved in positional relationships. This information is an important part of the data stored in the database. In general, unique identifiers on point and line features could be used for this purpose, however some large base data sets presently being used do not have such identifiers (Wan and Williamson, 1994a).

Wan (1993) developed and tested a simple database and associated software to maintain one particular type of positional relationship. The author found that, whilst the implementation was successful, there were a number of problems and limitations within the system. These problems were predominantly associated with;

- The multi-dependency of features. In some cases, one feature may be a base feature in one relationship, yet a related feature in another.

- The ability to select the area of change. In order to use this method it is necessary to be able to determine what features have actually undergone a positional change.
- The ability to reference lines that are not straight. A number of positional relationships occur between line features. However, it is possible that these line features will not be straight (ie. they include vertices).
- The desire of some users to offset features from their true positions.

One successful and quite interesting implementation of the database method is that described by Unkles (1992). This particular implementation is important for two reasons. Firstly, it is implemented and used on a working database. That is, it is an operational example of the database method. Secondly, the implementation is such that the positional relationship database is the primary source of spatial information for a number of data sets. That is, the table of relationship information does not exist supplementary to a spatial database. It is the spatial database. The methods and table definitions used for this system are discussed in Unkles (1994).

Another working implementation of the database method is described by O'Dempsey and Moorhead (1991). The importance of this particular solution is that it was implemented within a local government body and is used to maintain relative positions between features.

The database described by Corson-Rikert (1988) is designed to minimise the amount of updating necessary for a GIS. This is achieved by recognising areas where the same feature occurs in different data sets (eg. water boundaries might occur in a water features data set but also in a cadastral data set). Using this information it is possible to update only one instance of that feature. All other instances are automatically updated.

It should be pointed out that, apart from the example of Unkles (1992, 1994), all the above implementations have been relatively simple. That is, they have been implemented to maintain only one particular type of positional relationship. Furthermore, in all cases the methods proposed simply maintain a relationship rather than manage it. They do not determine if maintaining the relationship is, in fact, the correct action to take. Despite these problems however, these examples do show that the database method has some promise as part of a method for managing positional relationships in a GIS.

2.2.3 Object-Orientation

The principles of object-orientation are fast gaining recognition and support within many areas of the GIS community. This is also the case in the area of positional relationship management.

The ability of object-oriented systems to perform the task of managing positional relationships is without question. With careful design, the relationship information used in the database method could be implemented as part of object behaviour. Each object would store information about the positional relationships it is involved in and the nature of each relationship. This information would then be used should the feature undergo a positional change. That is, the act of the object's position being changed would trigger the process of positional relationship management.

It is not within the scope of this thesis to describe the concepts of object-oriented GIS, in particular the concepts of triggers and object behaviour, as these subjects have been discussed widely (see Kjerne and Dueker 1988, Frank and Egenhofer 1988/1989, Egenhofer and Frank 1988/1989, Oosterom and Bos 1989, Kemp 1990, Hesse 1991, and Maguire 1994). It is however important to look at the work done in the area of positional relationship management using object-oriented technology.

Hesse (1991) recognised that many of the concepts for 'associativity' (ie. positional relationships) within an object-oriented Engineering Modelling System (EMS) had already been researched and implemented by the Intergraph Corporation (Intergraph 1988). Further, it was recognised that this development, whilst being for a mechanical engineering application was similar to Intergraph's Topologically Integrated Geographic Information System (TIGRIS) (Intergraph 1989, 1991).

Wan (1993) also looked at object-orientation as a solution to the problem of managing positional relationships. It was concluded that this method showed a great deal of promise as it solved problems associated with software maintainability and extensibility and negated the need for user intervention. However, it suffered from the fact that the techniques involved are not widely known and understood, especially in the areas of design, database management and programming language.

Kjerne and Dueker (1986) also discussed object-orientation as a possible approach to managing positional relationships. In this particular example, the positions of certain objects are not represented by a set of absolute coordinates. Rather, the position of a feature is represented by a pointer to some other feature in the database. Thus, when it is necessary to determine the position of this feature, a calculation using the information stored in this pointer is used to determine its position relative to the other feature.

There is little doubt that, with careful design of the spatial database and a well considered model of the nature of the positional relationships between the objects in this database, the object-oriented approach can be used to successfully manage positional relationships. However one small problem exists. The model of the nature of positional relationships and the rules associated with their management have not yet been systematically investigated or documented. Thus, implementation of either the object-oriented or database solutions is not, at present, easily achieved as a formal definition of positional relationships has not been undertaken.

2.3 Conclusion

The purpose of this chapter was to introduce the concept of maintaining positional relationships and to review the three categories of methods proposed to perform this task. It has shown that all three approaches have certain advantages and disadvantages. Whilst the transformation method is relatively easy to implement, it cannot truly maintain certain types of positional relationships. On the other hand, whilst both the database and object-oriented methods can maintain all positional relationships, they can be initially difficult to set up and control.

Perhaps the most important finding from this chapter is that, in order for a comprehensive system for managing positional relationship to be effective, it is important to have some understanding of the nature of the relationships to be managed. For example, a common problem with each of the three methods reviewed is that there is no attempt to determine whether maintenance of a relationship is, in fact, the correct action to take. That is, it is possible that in some situations, maintenance of a relationship will not be required to preserve the spatial integrity of the GIS. Such situations may be dependent upon the type of positional change that has occurred or the form of the positional relationship. It will only be possible to identify these situations if the nature of the relationship and the factors affecting this nature are understood.

The purpose of this thesis is to investigate positional relationships and the issues and factors involved in managing them correctly. One of these issues, the maintenance technique, has been introduced in this chapter, however in order to perform this investigation correctly, it is necessary to have an understanding of the spatial data which has been collected or created using these relationships. Such an investigation into the data used by local government will be documented in Chapter 3.

3. Local Government and Geographic Information Systems

3.1 Introduction

One of the largest users of GIS technology is local government. Masser and Craglia (1995) suggest that 'local government applications probably account for somewhere between a quarter and a third of the total [GIS] market' in Germany and Great Britain. Marr and Benwell (1996), whilst studying the use of GIS in local government in New Zealand, found that, of the 64 (out of 85) councils which responded to their survey, 70% were using GIS technology. Craig (1994), found that all cities in the state of Minnesota (USA) with a population greater than 40000, use GIS. The use of GIS in German local government bodies is 'almost universal' (Masser and Craglia, 1995). It is not unreasonable to assume that local government in Australia would account for a similar percentage of the GIS market and that GIS usage within the local government sector would be at similar high levels.

Not only is the use of GIS throughout the local government sector widespread, the range of applications to which GIS can be put within individual local government bodies is also diverse. Evidence for this can be found in the fact that the department responsible for the implementation of GIS varies between councils. Marr and Benwell (1996) found that this responsibility, in New Zealand councils, might rest with the Planning, Engineering, Information Services or Administrative Sections of any particular council. In fact the range of possible uses for GIS technology within local government have led some authors to suggest that 'Local government is one of the most important groups of users of [GIS] (Campbell and Masser, 1992).

This diversity of possible applications and widespread use makes local government an ideal subject for studying the use of positional relationships within a GIS. Specifically, local government is the perfect subject for studying the need for, and implementation of, a system for managing these relationships. The diversity of possible applications means that many different types of positional relationships will be used by councils within their particular systems. The widespread use of GIS will allow for the construction of an extensive list of all types of positional relationships used by local governments.

Before attempting to determine exactly what types of positional relationships are used by local government, it is first necessary to determine exactly what spatial data are used. This can be achieved in 2 ways. Firstly, an investigation of the responsibilities of local government can be performed to determine those responsibilities which might require the use of spatial information. Secondly, a survey of a number of councils can be performed asking what types of spatial information they use to perform these responsibilities.

Unfortunately, in Australia, at least, the process of determining the responsibilities of local government is not simple. It has been noted that 'Local government authorities vary widely in area, population, revenue, organisation and activities, most markedly between, but also within, States' (Bowman, 1976 p66). These differences occur for many reasons, however one of the most important reasons is that, in each state, the powers of local government are controlled by various pieces of state legislation. A comprehensive study of the responsibilities of local government would thus require detailed examinations of each of these pieces of legislation. It has been noted by a number of authors that in each state, the Local Government Act constitutes one of the longest and most complicated pieces of legislation (ACIR 1984 p9, Power *et al* 1981 p43).

In order to avoid an examination of the legislation controlling local governments in every state, this study has been simplified to concentrate upon the responsibilities of local government in the state of New South Wales (NSW) only. It should be possible to apply the results of this investigation to local governments in other states as, 'whilst the pattern of responsibilities does vary across the States, there is considerable commonality' (ACIR, 1984 p10).

The following chapter investigates the spatial data used by local government in New South Wales. Firstly, a summary of those legislative responsibilities of local government requiring the use of spatial information is given. Secondly, a survey of the uses to which GIS technology is being put within a number of councils is presented. Finally, each of the spatial data sets identified as being used by local governments is described.

3.2 The Legislative Responsibilities of Local Government

The purpose of this section is to determine those responsibilities given to local government which will require the use of spatial data. This, will in turn give some insight into the types of spatial data that individual councils might use. However, it was noted in the introduction to this chapter that the legislative instruments controlling local government in Australia, and hence NSW, are long and complicated. Thus, any discussion of an investigation into this legislation will also be lengthy. This section will therefore summarise those responsibilities imposed upon councils. A more detailed investigation can be found in Appendix A.

In New South Wales, a number of Acts of Parliament have an effect upon the responsibilities of local government. The most important of these is the *Local Government Act, 1993*, however others include the *Environmental Planning and Assessment Act, 1979*, the *Bush Fires Act, 1949*, and the *Roads Act, 1993.*

Examples of those responsibilities that these acts give to councils which are of interest to this thesis are:

- the provision of environment conservation, protection and improvement services and facilities;
- the provision of fire prevention, protection and mitigation services and facilities;
- the management and control of land and property development;
- the management of public roads and reserves;
- the provision of public transport services and facilities;
- the operation of waste removal, treatment and disposal services and facilities;
- the operation of water, sewerage and drainage service facilities;
- the development of management plans for community lands;
- the maintenance of a 'land register' of all public lands;
- the control of the use of community land;

- the control of the construction of water supply, sewerage and stormwater drainage works;
- the development of asset management plans for all council assets;
- the production of annual state of the environment reports;
- the production of annual reports on the state of public works; and
- the management of coastal development.

This list shows that councils will find it necessary to maintain a diverse range of spatial data sets. These will include:

- environmental data;
- land use data;
- utilities data (water, sewerage and stormwater drainage);
- transport data, and
- cadastral data.

Unfortunately the list above only gives an indication of the categories of data that a council might use. In order to study the positional relationships used by councils it will be necessary to identify the individual data sets used. This can be done by studying the data used by a number of councils. Such a study is introduced in Section 3.3.

3.3 Survey of Local Government use of GIS

In the previous section it was shown that local governments in New South Wales have a number of responsibilities for which the use of spatial information might be important. Unfortunately, however, the pieces of legislation inferring these responsibilities do not describe, specifically, what spatial information should be used to fulfil these tasks. Thus, in order to determine what information councils are collecting and using within their particular GIS, it is necessary to actually ask a number of councils. This section introduces such a survey which was carried out over the period August 1994 to May 1995.

Of the 177 local councils in New South Wales, 36 were contacted by post and asked questions about the spatial information they maintained within their GIS. A further 3 councils, as well as the Land Information Centre (LIC), NSW Department of Land and Water Conservation, were visited and asked more specific, yet similar questions.

The criteria used to choose which councils to survey was as follows:

- All rural and greater metropolitan councils with populations greater than 50,000.
- All metropolitan councils with populations greater than 100,000.

Population information and descriptions of council type (rural, greater metropolitan or metropolitan) were obtained from LGSA, 1995.

The above criteria were designed to maximise the variety of councils, and hence spatial data types used, by guaranteeing there are both rural and metropolitan councils represented. The population test is a crude measure used to ensure that GIS technology is being used somewhere within the particular council surveyed. This test is based upon the assumption that councils with large populations will be in a position where GIS is both a necessary and affordable tool. Fortunately, of those councils that responded to the survey, only a small percentage (6%) did not, at that time, use a commercial GIS package.

Approximately 83% of councils contacted replied to the survey. This response rate, whilst only using a small sample size is similar to other such studies of GIS use in local government (Marr and Benwell, 1996).

The survey, posted to each council, asked the following questions:

1. Do you use a commercial GIS package for mapping?

This is a simple question aimed at determining whether the particular council is actually using GIS technology. As mentioned previously, all but a small number of respondents used a commercial GIS package somewhere within their organisation.

2. Do you use the LIC Digital Cadastral Database (DCDB) for your cadastral mapping?

3. If YES to 2. how often do you get updates and how are these updates incorporated into your database? (ie what process is used?)

4. If NO to 2. do you use the cadastre as a base for your mapping, if so what is your source and how do you maintain it?

Questions 2-4 deal with the particular council's use of cadastral information within their organisation. It will become apparent in later sections that the cadastre is a very important data set, used by most local government bodies. The maintenance of the currency of this information is very important to councils and the processes used for performing this function are very much dependant upon the source of the data. The results from these questions will be discussed in Section 3.5.

5. Have you heard of the problems of associatively (vertical topology) and what do you understand by them.

Question 5 examines the understanding of the problems associated with using and maintaining positional relationships in a GIS. Unfortunately this question was not well answered. This may be due to a general lack of understanding of these problems or to poor wording of the question. Some of the answers to this question did however reveal that a number of respondents had recognised that constant updating of certain spatial features was affecting the integrity of other data sets within their system.

6. What other mapping layers do you maintain as part of your GIS? (eg. water, sewer, LEP zoning, bus routes, text, etc.).

The answers to this question showed that the spatial data being collected by individual local government bodies for use in their GIS varies greatly between councils. They also showed that the degree to which each council's GIS had been developed varied markedly. At the time of the survey, some of the responding councils had sophisticated and extensive systems (one council maintained a total of 135 graphic and 28 text map layers, another claimed to have over 500 layers). Other systems, however, were still very much in a development stage, with few if any data sets having been captured. This, however, allowed for an insight into what councils expected from their systems before implementation. The results from an analysis of the responses to this question will be discussed in detail in Section 3.4.

7. Do features in any of the above layers have direct relationships (eg. offset, coincidence, bearing and distance) to features in other layers? If so, what are they and how are they maintained within your system?

   This question is really asking how, and why, the data for these layers was captured and whether the information required was really the relationship between features or the absolute position of a particular feature (eg. is it more important to now where a feature is in relation to a nearby fencelike rather than to some datum point).

8. Finally, are there any instances, where the above relationships come secondary to maintaining the integrity of the database in other ways (eg keeping straight lines straight)?

Questions 7 and 8 are difficult questions and were, unfortunately, poorly answered. The answers did show, however, that at least some councils had considered the positional relationships that exist between the spatial features they use.

The reason for performing this survey was primarily to gather information about the types of spatial data that a local government body in NSW might store within its GIS. An analysis of the responses to each question could then lead to an understanding of the nature of each of these data sets and the processes used to create them. The survey also attempted to gain an insight into whether or not the problems associated with positional relationships are recognised within local government.

Whilst the qualities of the responses to the survey were variable, the data gained has been invaluable to this thesis. It has shown not only that the types of spatial data being used are extraordinarily diverse, but that the understanding of the nature of the data and the problems associated with it are also varied. That is, whilst some respondents had recognised that constant updating of individual data sets was affecting the integrity of their GIS, others showed no understanding of the problem.

This survey whilst not being the first investigation into local government GIS usage, has provided an important insight into the use of spatial data in these organisations. It is therefore a valuable contribution to the understanding of GIS usage in local government.

3.4 The Spatial Data Used by Local Government

Question 6 of the survey of local governments asked each council to list the types of spatial information that has been, is being and will be collected and used within their particular GIS. As mentioned previously, using the responses to this question it is possible to determine a number of things about the use of GIS in local government in New South Wales.

Firstly, it is apparent from the amount and type of data collected that, whilst some councils have sophisticated and well established spatial databases, others are only just beginning to collect data. The differences between the expectations of those councils beginning data capture and the realities of those councils who have undergone this process, whilst not within the scope of this investigation, are in some cases large.

Secondly, the use to which GIS technology is being put within local governments in New South Wales varies greatly between individual councils. This result confirms the findings of Marr and Benwell (1996) and hence justifies the decision to study local government for this project.

By collating the answers to Question 6 it is possible to identify a total of 76 separate spatial data sets which are being maintained by at least one of the councils surveyed. It should be noted that, whilst a number of the councils contacted actually claim to maintain many more than 76 data sets, quite often, a number of these sets actually represent subsets of the same data. For example, whilst a council may maintain a different layer to represent each of the road types in their particular area, for the purposes of this study all these layers are counted as one data set only.

The list of 76 specific data sets covers a large section of the spatial information spectrum, including administrative boundaries, utility information and environmental data. Of the data sets identified, a few core data sets are used by most councils. These data sets include cadastral information, local environment plans (LEPs), contours and text. A large percentage of the data sets identified, however are used by only one or two councils.

In order to understand the positional relationships between features in each of these data sets, it is first necessary to gain some understanding of the data themselves. Thus, a detailed investigation of each of the 76 data sets has been performed to determine exactly the nature and use, in a local government context, of that particular piece of information. This investigation involved determining:

- the purposes for which the data set is used;
- the spatial features used in the data set to represent real world features;
- how the spatial information is created or collected;
- which other data sets contain features to which features in this data set are related; and
- the nature of any positional relationships used.

The following sections give a summary of the results of this investigation. Each of the specific data types has been placed into a category based upon the type of data represented. A more detailed discussion of each of the 76 data sets can be found in Appendix B.

It should be pointed out that the lists of data sets appearing in the following sections are by no means exhaustive. They are merely the results of a survey of a number of the larger councils in New South Wales. It is therefore, possible that individual councils may find it necessary to maintain data sets other than those listed here. Furthermore, it is not suggested that the categorisation method used here is perfect. It may be possible that a data set listed in one category here may also belong in another category. The categorisations have been developed simply to allow ease of presentation of the data.

3.4.1 Airports

Information about airports is not used by many councils. This is due mainly to the fact that no metropolitan councils and only a few rural councils are responsible for their management. However, increasingly, the positioning of runway approaches is being recognised as having a large effect upon the quality of life of those people living underneath these approaches. This is evidenced very well in the eastern and inner western suburbs of Sydney where the recent opening of a third runway at Sydney's international airport has caused great concern within councils affected by the increased air traffic. It is therefore conceivable that a number of these metropolitan councils may start to collect information about runway approaches.

Table 3.1 lists those spatial data sets identified as being specifically associated with the management of airports and airport approaches. It also gives the percentage of surveyed councils which maintain this information.

The data sets listed in Table 3.1 are, of course, not the only information relating to airport management that a council might require. Road networks and the positions of buildings and other structures may also be used. This information however, is more general in nature and will be mentioned in later categories.

Spatial Data Type	**Council Use**
Airport Approaches	2.9%
Runway Centreline	2.9%
Tarmac & Taxiways etc	2.9%

Table 3.1 Airport Data Sets.

In general, the features contained within the airport data sets are line or area features which are used for asset management purposes or, in the case of airport approaches, as a planning tool. The positions of these features are usually related to a survey datum (Australian Map Grid (AMG), Integrated Survey Grid (ISG)) through relationships to the Runway Centreline (Fraser, 1995). The relationships between these features, especially runway centrelines and airport approaches are complex yet important.

3.4.2 Asset Management

As mentioned in Section 3.2.1.3, the *Local Government Act 1993* requires local governments to adhere to Australian Accounting Standard 27 (AAS27). This standard requires councils to capitalise all their assets (Grant and Gordon, 1993). These assets include a number of items which have certain spatial attributes, ranging from public buildings (civic centres, libraries etc) to garbage bins, park benches and street signs.

In order to manage these assets, a number of councils are using GIS technology to determine what assets they have and where they are. It is then possible for these councils to develop effective maintenance procedures for these assets (Roorda, 1995).

Table 3.2 lists those spatial data sets identified as being specifically associated with asset management as well as the percentage of responding council which claimed to maintain this information.

Spatial Data Type	Council Use
Council Managed Land	17.7%
Park Furniture	2.9%
Street Furniture	17.7%
Other Assets	11.7%

Table 3.2 Asset Management Data Sets.

Point and area features predominate the asset management spatial data types. Unlike many of the data sets used by councils, each asset data set usually consists of a set of discrete features whose position is unrelated to other features in the same data set. That is, one point or area will be used to represent one particular asset, the position of which is completely unrelated to nearby assets. The position of each feature will, however, usually be related to some feature, usually the cadastre or road centreline, in another data set used by council.

There are a number of other assets that many councils will have which are not listed in Table 3.2. For example Stormwater Drainage Networks and Road Networks can both form part of the assets of a council. The spatial information for these data sets has other purposes other than for asset management and hence have been listed in other categories.

3.4.3 Administrative Boundaries

The basis of the land tenure system used in New South Wales is the cadastre. All councils contacted for this survey, which use GIS, use and maintain a cadastral data set. Furthermore, in most cases, it is used as a base to which many other spatial features are related. The cadastre is an enormously important data set for local government and will be discussed in some detail in Section 3.5. There are, however many other administrative boundaries which councils may use in the management of their areas of operation.

Table 3.3 lists the administrative boundaries identified as being used by the local government bodies responding to the survey and the percentage of those councils which use them.

None of the councils surveyed use all of the data sets listed in Table 3.3. However a number of these data sets are used by many councils. For example, it was mentioned previously that the cadastre is mapped by all councils using GIS. It can also be seen that data sets such as Local Environment Plan zones and Easements are used by a majority of the councils surveyed. Other data sets, however, tend to be unique to particular councils.

In general, the definition of a particular administrative boundary will be such that it actually is related to some other boundary. For example Road and Rail Corridors are, for the most part, a subset of the cadastre. Similarly Aboriginal Land Council Districts are defined as being coincident with the cadastre at the time that the boundaries were defined (Fitzmorris, 1995). Unfortunately, other data sets such as Suburb, Postcode and Census District Boundaries do not necessarily have a direct relationship with one other data set. Rather, the positions of features in these data sets are defined using features from a number of other data sets. For example, electorate boundaries can be defined as having some relationship to road centrelines, waterways, electricity transmission lines and the cadastre, amongst other things. Other data sets, such as suburb boundaries, will contain features which have relationships to other features for only part of their length and for the remainder will have no relationships to other features.

Spatial Data Type	**Council Use**
Agricultural Land Classification	5.9%
Building Lines	2.9%
Cadastre (future)	17.7%
Cadastre (past)	8.8%
Cadastre (present)	94.1%
Census Collection Districts	14.7%
County Boundaries	11.8%
Development Control Plans	14.7%
Easements	35.3%
Electorates	2.9%
Fire Brigade Districts	5.9%
Leases	2.9%
Local Aboriginal Land Councils	2.9%
Local Environment Plans - general provisions	2.9%
Local Environment Plans - zoning	73.5%
Local Government Area	17.7%
Mine Subsidence Districts	5.9%
Multiple Assessments	2.9%
National Park/State Forest Boundaries.	17.7%

Parcels	8.8%
Parish Boundaries	20.6%
Postcode Areas	2.9%
Precinct/Neighbourhood Areas	8.8%
Proclaimed Survey Areas	2.9%
Properties - Rateable	2.9%
Properties - Other	5.9%
Regional Environment Plans	2.9%
Road and Rail Corridors	20.6%
Rural Lands Protection Districts	2.9%
Sect. 94 EP&A Act	2.9%
State Border	5.9%
Suburb/Locality Boundaries	35.3%
Town Area	2.9%
Wards	29.4%

Table 3.3 Administrative Boundary Data Sets.

The source of a number of the Administrative Boundary data sets used by local government is quite often outside the particular council using it. Thus, these councils have no control over data sets such as Suburb and Locality Boundaries, National Park and State Forest Boundaries and, in some cases, the Cadastre. This fact plays an important role in the management of positional relationships existing between features in these particular data sets and features in other data sets.

3.4.4 Environmental Data

The management and protection of the natural environment has become a very important function of local government. The reporting requirements under the *Local Government Act, 1993,* require councils to report extensively upon the state of the environment in their particular areas of control (see Section 428, *LGA, 1993*). Furthermore, consideration of environmental information is also important when reviewing various development applications. Thus it would seem that information about the environment is very important to local government.

Table 3.4 shows the environmental data sets being used by the councils surveyed along with the percentage of those councils using this information.

Spatial Data Type	**Council Use**
Endangered Fauna and Flora	11.8%
Land Slip Areas	2.9%
Natural Drainage	11.8%
Natural Water Features	17.7%
Slopes	5.9%
Soil Landscapes	11.8%
Vegetation	11.8%
Water Catchment Areas	5.9%

Table 3.4 Environmental Data Sets.

The data sets listed in Table 3.4 are diverse in both what the data represents and the purposes for which the data is collected. For example, natural drainage information is very important for a number of the functions performed by local government. It can be used in prediction of those areas prone to flooding as well as a base for certain administrative boundaries. These are two completely separate uses for the same piece of data.

The nature of the data in the environmental data sets is also diverse. Some contain features whose positions are very much dependent upon the positions of features in other data sets. For example, Slope maps are very much dependent upon contours and other height information. Water Catchment Areas, on the other hand, are dependent upon contours and natural drainage. The features in other data sets however, are more independent and thus, whilst they may have been created with respect to features in other data sets (eg. Endangered Fauna and Flora might be mapped with respect to the Cadastre), the positions of these features are not dependent upon their related features. Yet other environmental data sets consist of features whose positions have been determined with respect to some mapping datum.

3.4.5 Environmental Hazards

In January 1994, bushfires ravaged many parts of New South Wales causing many millions of dollars of damage. These fires are just one of the most recent examples of how much at the mercy of the environment our lives are. Floods and bushfires are a constant threat and hence councils need to be constantly aware of the potential damage they might cause and areas at risk.

Councils have a number of responsibilities with respect to the prevention and control of damage due to a number of possible environmental hazards. Table 3.5 lists those data sets, and the percentage of the surveyed councils using them, which are directly linked with these hazards.

The nature of environmental hazard data is very much dependent upon the hazard involved. In the case of bushfire data, for example, councils might collect information pertaining to areas of high risk (dependent upon slopes and available fuel, amongst other things) as well as areas where hazard prevention has been undertaken (Murray, 1995). In the case of flood data, areas of high risk are determined using a flood model and contour information. In both these cases the resultant data will be in the form of polygons representing areas of differing risk. Evacuation sites however will usually consist of discrete point data.

Spatial Data Type	Council Use
Evacuation Sites	2.9%
Fire - Bushfire Data	11.8%
Fire - Hazard Areas	14.7%
Flood Lines/Zones	23.5%
Other Hazard Areas	5.9%

Table 3.5 Environmental Hazard Data Sets.

The data set labelled Other Hazards in Table 3.5, includes such things as the positions of industries involving hazardous materials and the sites of former toxic areas. This information is used for planning and coordination in emergency situations.

3.4.6 Transport

In Section 3.2.2.6 it was noted that the *Roads Act, 1993* places responsibility for certain local roads in the hands of local government. This means that councils will be responsible for maintaining the road pavement as well as any other features of these roads. These features may include kerb and guttering, median strips and bridges. In order to be able to manage these features, it will be necessary for councils to maintain certain spatial information about them.

Information about roads however, is not the only Transport data set that a council might use. Table 3.6 indicates the transport related data sets maintained by the local governments surveyed and the percentage of these councils maintaining each particular set.

Spatial Data Type	Council Use
Bridges	5.9%
Rail Centrelines	2.9%
Road Centrelines (incl. Cycleways)	29.4%
Road Pavement	8.8%
Routes	17.7%

Table 3.6 Road Transport Data Sets.

Councils are also responsible for the collection of garbage and may be responsible for providing public transport within their area of control. Route information may be used by councils to monitor these functions. Transport information can also play an important role in planning.

The relationships between features in these data sets and other features vary greatly. In general, route information will be directly related to features in some other transport data sets (eg Road Centrelines). Road centrelines however, are not usually directly related to any other feature.

3.4.7 Utilities

The amount, and type, of utility information used by the councils surveyed varies markedly. This is due to the fact that the need to provide these services varies between different councils. Whilst most metropolitan councils are not, for example, responsible for the provision and maintenance of water and sewerage networks, most large rural councils are.

The types of utility information being used by the surveyed councils can be seen in Table 3.7 along with an indication of the percentage of those councils using each data set.

Spatial Data Type	Council Use
Electricity Transmission Lines	5.9%
Sewerage Reticulation Network	32.4%
Stormwater Catchment Areas	2.9%
Stormwater Drainage Network	26.5%
Telecom Public Phones	2.9%
Telephone Lines	2.9%
Water Reticulation Network	29.4%

Table 3.7 Utilities Data Sets.

The supply of clean drinking water, the removal and treatment of waste water and the removal of stormwater are three very important functions that many councils perform. Knowledge of the positions of the infrastructure required to perform these functions is essential for many reasons. Furthermore, this infrastructure also forms part of a council's asset base (Roorda, 1995). Hence information on the condition of pipes and fittings is necessary in order to continue an effective maintenance program. For those councils which do not provide these services, it is still in the interest of council to have some knowledge of the positions of underground facilities to aid in the planning process.

Whilst local councils are not responsible for maintenance of electricity transmission or telecommunications networks, it is in the interest of all land developers to know where these facilities are. As councils deal directly with these developers and, in some cases, are land developers themselves, some councils find it useful to maintain this information (Fraser, 1995).

3.4.8 Survey

A small number of the councils surveyed also maintain certain amounts of survey (mapping) information. These include the positions of survey control (plane and height) marks as well as standard map grid (eg. Australian Map Grid (AMG), Integrated Survey Grid (ISG)) data. This information is used for varying reasons including registration of images, adjustment of inaccurate data sets as well as for cartographic output.

Table 3.8 shows those survey related data sets, and the percentage of council using them, identified from the survey.

Spatial Data Type	**Council Use**
Aerial Photography	2.9%
Map Grids	5.9%
Survey Control	11.8%

Table 3.8 Survey Data Sets.

An increasing number of councils are using aerial photography as part of their GIS. The information within these images can be used for a number of tasks ranging from the creation of terrain models to monitoring of swimming pools in backyards and as a backdrop for cartographic output.

Unlike all other data sets identified from this survey, aerial photography is a raster data set. That is, rather than consisting of point, line and area features representing identifiable real world features, they are constructed from a series of uniform grid cells (pixels), each cell representing an area of the earth's surface. As such, whilst various features may be recognisable to the human eye in the image, they are not actually represented within the spatial data set. It is hence very difficult to define positional relationships between features in such data sets and features in other data sets. For this reason, image and other forms of raster data sets have not been considered for this study.

3.4.9 Other

There are a number of other data sets identified from the survey of local governments. They are listed in Table 3.9 along with an indication of the numbers of surveyed councils using this data.

Other Spatial Data Type	Council Use
Animals	2.9%
Contours	50.0%
Heritage/Aboriginal Sites	23.5%
Land Use	11.8%
Paracentroids	2.9%
Text	44.1%
Sampling Sites	2.9%

Table 3.9 Other Data Sets.

Many councils regard text data sets as being very important. This is evidenced by the number of councils using this information. Text is used primarily for cartographic output and is usually related specifically to features in other data sets. These related data sets range from street networks to cadastral maps and utility information. The relationship between each text element and its associated feature is vitally important. Even small changes to the associated feature can have major effects upon the quality of hardcopy output.

Another data set used by many councils (50% of those surveyed) is contour information. This information can be used for many reasons in both the engineering and planning fields.

Yet other important data sets are those that show the positions of areas of heritage and cultural value and those that indicate the current use for particular parcels of land. These data sets are used primarily for planning purposes.

3.5 The Digital Cadastral Database

A significant result from the survey of local governments was the fact that, of all surveyed councils actually using or planning to use GIS, all used, or planned to use, the cadastre as one of their data sets. This result is, of course, not surprising as the cadastre forms the basis for many of the functions of local government (eg. rating, development control, etc). It would therefore appear that, in order to fully understand the nature of a local government GIS, it is important to have an understanding of these cadastral data sets.

In general, a cadastral data set is referred to as a Digital Cadastral Data Base (DCDB). It has been suggested that these data bases 'provide the fundamental base or, at least, form an important component of integrated LIS/GIS worldwide' (Hesse, 1991). In fact they are perceived to be so important that, in all states in Australia, the relevant state government has undergone a process of capturing cadastral information for the entire state. For a review of the DCDB for each state, and in New Zealand, see Wan and Williamson (1995).

In New South Wales, the DCDB is maintained by the Land Information Centre (LIC). Of the councils surveyed, approximately 50% use cadastral data from the LIC. The remaining councils have captured this information themselves. The difference in cadastral data source means that those councils which use the LIC DCDB have different data sets to those who don't. This is due mainly to the original source of the cadastral information and the methods used to capture it. It is important therefore to take a brief look at the history of the LIC's DCDB and in particular its accuracy.

3.5.1 The Land Information Centre's Digital Cadastral Database

The DCDB for NSW was captured by the LIC over a 7 year period (1988 - 1994). Data was captured from a variety of sources using a variety of capture techniques. In some cases the cadastral data came from existing digital databases such as those maintained by the Sydney and Hunter Water Boards. Data was also digitised by consultants using hardcopy cadastral mapping. This hardcopy came in the form of mapping sheets at scales ranging from 1:500 to 1:100,000 (LIC 1994a). Raster scanning of this same cadastral mapping was yet another technique used to capture the data.

The coordinate systems used for capture of the data varied depending upon the data source. In the case of the smaller scale maps (1:25,000 to 1:100,000) geographic coordinates (latitude and longitude) were used. The large scale maps (1:500 to 1:10,000) were captured using Integrated Survey Grid (ISG) coordinates (see Dept of Lands, 1976). For ease of storage, all maps are stored in geographic coordinates with a precision of 0.0001 seconds of arc.

The DCDB consists of a series of map layers representing different legal and administrative boundaries throughout the state. These map layers are described in LIC (1994(a)) and include:

- Parcel Map (cadastre)
- Easement Map
- State Map
- County Map
- Parish Map
- Local Government Area Map
- National Park Map
- State Forest Map
- Mine Subsidence District Map
- Proclaimed Survey Area Map
- Stratum Map
- Local Aboriginal Land Council Map
- Suburbs Map

The smallest accountable entity within the DCDB is a polygon of which there are approximately 4.2 million for the state. Identifiers, in the form of a tag, exist for all polygons and only those lines which are not cadastral boundaries (see below). To aid in data management, the DCDB is split into a series of map sheets. Each map sheet contains roughly 8,000 polygons (LIC, 1994c).

Originally, each polygon in the cadastral map was given an identifier which represented the status of that particular polygon. Under this system, a polygon for Main St would be tagged 023/MAIN and Lot 1, DP 236447 was tagged 013/1//236447. The first number in each tag indicates the legal status of the land (ie. 023 is a road and 013 is a cadastral lot). This tagging system however proved inadequate, as tags were not necessarily unique (eg. there is more than one Main St. in the NSW). The LIC has replaced all tags with unique identifiers to overcome this problem.

As mentioned previously, line features representing cadastral boundaries within the DCDB do not have identifiers. There are however, line features which do have identifiers. These lines are placed within the DCDB for special purposes such as to create individual polygons for separate road sections (such lines have the identifier INT) and to mark the position of other administrative boundaries (tagged BDY). Figure 3.1 shows a typical section of the DCDB.

With the introduction of unique identifiers a certain amount of attribute information about each polygon is also supplied. This information includes accuracy codes, map sheet numbers, local government area, lot and deposited plan number. This information allows users to access specific spatial data from both the graphical database as well as via a relational database.

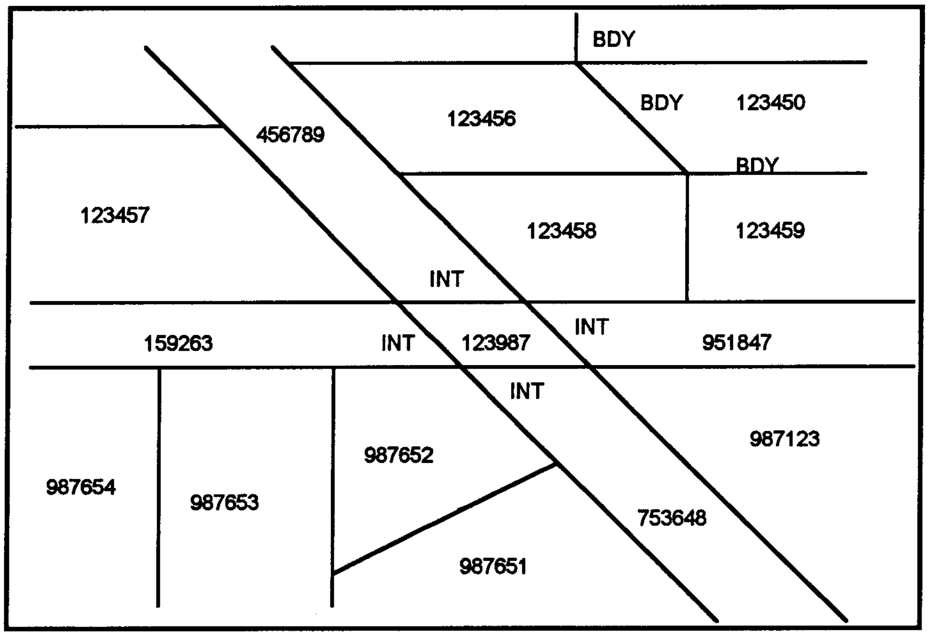


Figure 3.1. The Digital Cadastral Database. Each polygon has a unique identifier allowing the user to access attributes about that polygon in a relational database. In this figure the polygon 123987 is the centre of a road intersection. The line features forming this polygon are thus identified with the tag INT. The polygons 123456 and 123450 are in fact the same cadastral lot, however another administrative boundary crosses this lot shown by the line tagged BDY.

3.5.1.1 *DCDB Accuracy*

When determining the usefulness of a particular DCDB, the accuracy of the data plays an important role. As Hesse *et al* (1990) point out, the usefulness of the DCDB is very much dependent upon the way the cadastral information was captured as well as the graphical accuracy of the information.

From the variety of sources and digitising methods used to capture the DCDB it is not difficult to understand that the accuracy of the data varies markedly throughout the state. It is the policy of the LIC to maintain the accuracy of the DCDB according to the horizontal accuracy standard defined by the former National Mapping Council (Wan and Williamson, 1995). This standard states that:

> The horizontal accuracy of standard published maps shall be consistent with the criterion that:
>
> > not more than 10% of points tested shall be in error by more than 0.5mm.

This standard was designed for hardcopy maps and hence the LIC maintains the accuracy of the DCDB at that of the original source data. In fact, Section 9.3 of the specifications used for capture of the DCDB (LIC 1994a) states that:

> 90% of all points tested shall lie within 0.5mm of their true position at map scale.

Each map is given an accuracy code which is directly related to the scale of the source document. These codes are listed in Table 3.10.

Whilst these codes are used to give an indication of the accuracy of a particular map, they do not represent the true accuracy of the DCDB. To the author's knowledge no true test of the accuracy over a large area of the DCDB has been performed to date.

Code	Map Scale	0.5mm on Ground
A	1:500	0.25m
B	1:2000	1.0m
C	1:4000	2.0m
E	1:25000	12.5m
G	1:50000	25.0m
H	1:100000	50.0m
WB	Sydney Water Board	
HE	Hunter Water Board Electronic Data	
H2	Hunter Water Board 2000 data	1.0m
H5	Hunter Water Board 500 data	0.25m

Table 3.10. Accuracy Codes for DCDB. (LIC, 1994b).

The accuracy of the DCDB has been of concern to some users of the data. In fact the forum mentioned in Chapter 2 dealt mainly with the issue of if and how this accuracy should be improved. It will be shown in Chapter 5 that any process to improve the accuracy of a data set such as the DCDB will have an important affect upon the management of positional relationships for that data set.

3.5.2 Local Government and the DCDB

It was noted earlier that digital cadastral databases 'provide the fundamental base or, at least, form an important component of integrated [GIS] worldwide' (Hesse, 1991). It has been noted by Wan and Williamson (1995) that 'the [DCDB] is widely used by government agencies and utility companies as a basic reference for land administration, local government administration, facilities management, planning and asset management'. It has been shown that all of the functions listed by Wan and Williamson are functions carried out by local government. Thus it can be expected that councils will also use the DCDB as a base for their GIS. In order to determine if this assumption is correct it is necessary only to look at the positional relationships used between features in the data sets identified in the local government survey.

Of the 76 spatial data sets identified from the survey of local governments over 30% have a direct relationship with the cadastre. That is, the positions of certain features within these data sets are absolutely dependent upon cadastral boundaries. A further 30% of these data sets can be, and usually are, related to the cadastre.

Table 3.11 lists the 10 most common data sets (after the Cadastre) identified from the survey. Of these data sets, features in the Local Environment Planning Zones, Easements, Suburb/Locality Boundaries, and Wards data sets are completely dependent upon the cadastre. Features in the Text, Sewerage Reticulation Networks, Centrelines, Water Reticulation Networks, Stormwater Drainage Networks and Heritage/Aboriginal Sites data sets can be, and usually are, related in some way to features in the cadastre. Furthermore, the relationships between features in the Flood Lines/Zones and the Cadastre play an important role in land use planning for local government. It can thus be seen that the DCDB plays an important role as the base to which many features in other data sets used by councils are related.

Unfortunately, however, the cadastre itself is a dynamic data set. That is, at any one time any of the features within this data set can be subject to some form of positional change. The LIC reports that it performs approximately 1200 changes to the DCDB every week (LIC, 1994b). These changes can occur for a number of reasons and result in new boundaries appearing and old boundaries disappearing constantly. The forms of positional changes that may occur in a spatial database will be discussed in Chapter 5.

Spatial Data Type	Council Use
Local Environment Plans - zoning	73.5%
Contours	50.0%
Text	44.1%
Easements	35.3%
Suburb/Locality Boundaries	35.3%
Sewerage Reticulation Network	32.4%
Centrelines	29.4%
Wards	29.4%
Water Reticulation Network	29.4%
Stormwater Drainage Network	26.5%
Flood Lines/Zones	23.5%
Heritage/Aboriginal Sites	23.5%

Table 3.11. The 10 Most Common Data Sets. The most common spatial data sets (after the cadastre) identified from the survey of local governments and the percentage of surveyed councils using this data.

Thus, whilst the DCDB is a very popular and important base for local government, due to its nature, it does not make for a very reliable base. It will be shown in Chapter 5 that the dynamic nature of the cadastre, means that it is difficult to maintain relationships between it and other data sets as positional changes have an effect upon positional relationships.

3.6 Summary

The purpose of this chapter was to investigate the types of spatial information used by local government in New South Wales. As a result of this investigation it was found that the legislative requirements imposed on councils by the NSW State Government, whilst requiring councils to provide certain services and perform certain functions, do not describe how they are to perform these tasks. Thus, whilst the diversity of spatial data required by individual councils will be large it possible that individual councils will use different spatial information to perform similar tasks.

Therefore, in order to determine the types of spatial information councils use, it was necessary to ask them. A number of larger rural and metropolitan councils were surveyed and asked, amongst other things, to list the types of spatial information they maintained as part of their GIS. The results of this survey led to the identification of 76 separate data sets used by at least one of these councils.

An investigation into each of these 76 unique data sets revealed that the spatial data used by local government in New South Wales is extraordinarily diverse. It ranges from administrative data sets through utility information to environmental and asset data. It consists of vector data, containing point, line and area features and raster data in the form of aerial photography. Some of the features maintained within these data sets are dependent upon features in other data sets whilst other features are independent.

The investigation also showed that the cadastre is one of the most important data sets used by local governments. Further, this importance is such that many of the other data sets used by councils are related, via various positional relationships, to the cadastre.

The next step in the investigation of the nature of positional relationships and the factors involved in the management of these relationships, is to study each of the positional relationships used in the creation of each of the 76 local government data sets. This study will be described in Chapter 4.

4. THE NATURE OF POSITIONAL RELATIONSHIPS

4.1 Introduction

The fact that relationships exist between spatial features is without question. In fact it has been suggested that the study of these relationships has been fundamental in the development of GIS technology (Abler 1987, Mark and Frank 1991, Frank and Campari 1993, Egenhofer and Mark 1995).

Laurini and Thompson (1992, p214) divide the study of spatial relationships into the following categories:

- metric relations (distance, direction);
- topological relations (connection, contiguity, orientation); and
- order relations (inclusion).

They further suggest that those people who use spatial information 'have known and worked with many concepts like containment, neighbours, and distances for a very long time'.

Pullar and Egenhofer (1988) also identified a number of different categories of relationships between spatial objects. These include:

- topological relationships;
- comparative relationships (eg. on, in, at, etc);
- directional relationships (eg. north, south, up, down, right, etc);
- distance relationships (eg. A is 24 km from B); and
- fuzzy relationships (eg. next to, far from, etc.).

A number of these types of spatial relationships are used extensively within GIS to provide certain functionality. For example, topological relationships are used for a number of the spatial queries available in modern GIS packages. These relationships are preserved under continual transformations and allow for the execution of connectivity (used in networks) and neighbourhood queries (Egenhofer and Herring, 1994).

Other categories of relationships, whilst existing within spatial data, are not used extensively by GIS packages. Directional relationships, for example, are 'commonly used to describe the relative relationship of two points' yet 'functions to comprehensively determine [them]...are not commonly found in commercial products' (Caldwell and Graff, 1993).

It is not the intention of this chapter to prove the existence of relationships between the features in a local government GIS. Rather, it is intended to investigate those relationships used by councils for positioning certain spatial features within these systems. That is, an investigation of positional relationships will be performed by looking at the types of relationships used as well as the circumstances under which this use occurs.

The reason for performing this investigation is to use the results to determine how best to manage positional relationships within a local government GIS. The management process will revolve around a set of rules which allow the user to determine the correct action to take with respect to a positional relationship if it is affected by a positional change. This action will be dependent upon the nature of the affected relationship.

Furthermore, as Pullar and Egenhofer (1988) noted whilst developing formal definitions for topological relationships;

> A formal definition for spatial relationships will be helpful for providing a collection of expressions which can be used for any application with spatial data.

Thus the act of developing a formal definition for each positional relationship may enable the development of techniques to manage that relationship correctly.

The first step in investigating the positional relationships used in local government data is to look at those positional relationships that have been identified in other fields of GIS usage. Given the broad range of local government data sets identified in Chapter 3, it is conceivable that the relationships identified in these other fields may also be used by local government. This chapter starts by looking at previous research in the areas of utility databases and administrative boundaries as well as the functionality provided by a number of commercial GIS packages for positioning spatial features.

The second step is to actually study the data sets used by local government with particular emphasis upon how the information is collected or created and hence the positional relationships used, or created as part of this process. It is then possible to determine which, if any, of the previously identified relationships are applicable to the local government situation.

Using the information collected from the first sections of this chapter, the final section will look at those aspects of the nature of a positional relationship which will play a role in the management of that relationship. This will include the development of a list of the fundamental positional relationships used in local government GIS along with the introduction of a technique for classifying relationships based on the purpose for which the relationship exists.

4.2 The Use of Positional Relationships between Features in a GIS

As the name implies, a positional relationship is a relationship between the positions of features within a GIS. Unlike other categories of spatial relationships however, they are not inherent in the nature of spatial data and do not necessarily exist for every feature in a particular data set. Rather, they are used at the time of data capture or creation, to determine where, in a cartesian sense, one feature is with respect to other features. That is, unlike topological or other categories of relationships, they are introduced into the data set by the user.

It was noted in Chapter 1 that the existence of positional relationships has been recognised by a number of authors. Unfortunately, whilst acknowledging that these relationships exist, very few of these authors have actually investigated what form they take.

A number of authors give examples of possible types of positional relationships. For example, 'offsets' (Wan and Williamson, 1994a), 'coincidence' (Corson-Rikert, 1988), 'relative position' (O'Dempsey and Moorhead, 1991), and 'bearing and distance offsets' (Hebblethwaite, 1989) are all mentioned yet the physical nature of these relationship types have not been comprehensively investigated.

The following sections look at three different areas of positional relationship usage in the GIS user community. The first two sections review the relationships identified within two particular fields of the GIS industry. The third section looks briefly at the coordinate geometry (COGO) techniques provided to users by two commercial GIS packages.

4.2.1 Positional Relationships in the Utility Industry

It was noted in Chapter 2 that the importance of positional relationships to the utility industry is such that the majority of work on these relationships has been associated with this application. It was further noted in Chapter 2 that this research has tended to concentrate upon the development of methods for maintaining positional relationships. That is, little investigation of the types of positional relationships used by the industry has been undertaken. It is hence unclear whether these techniques will work for all positional relationships in all situations.

Despite this lack of research, it does however appear that features within utility spatial databases are positioned in one of two ways. Firstly, they can be positioned relative to some base (usually the cadastre (DCDB)) with little, if any, regard to the accuracy of the position of the feature other than that relative to the base. O'Dempsey and Moorhead (1991) refer to this method of positioning as a 'relative position'. Clatworthy (1994a) refers to such databases as 'inaccurate utility databases' since the positional accuracy of the utility features contained within them is, to say the least, unknown.

The second method used for positioning utility features, and the method to be discussed in detail here, is to position the utility feature in the GIS using actual physical measurements, taken in the field. These measurements may be made using coordinate based technologies (eg. GPS) or may be in the form of positional relationships between the feature of interest and some base feature.

Unkles (1992), whilst relating the story of the development of a GIS in a utility organisation noted that eight different models for the fixing of points and drawing of lines using positional relationships had been identified. Unfortunately, in this particular paper, the author did not define the nature of these models. However, in a later paper the author looks closely at a number of point and line relationships (Unkles, 1994).

In a draft document entitled "Advantages of a structured relational database for the creation, maintenance, transfer, and outputting of computerised maps" Unkles (1994) suggests a possible method for storing and managing positional relationship information within a GIS. As part of his document, the author also discusses the nature of the relationships to be maintained by the proposed method. It is therefore useful to look at these relationships.

Unkles uses the term 'model' to define a positional relationship and looks at point models:

> *A method which describes the way a point is positioned and how its location is fixed within the spatial environment*

and line models:

> *A method which describes how a line is generated within the spatial environment and its relationship with or to other partial entity features*

[An *entity feature* is defined as being a spatial object of 0 (point), 1 (line), 2 (polygon) or 3 (volume) dimensions]

The document identifies a number of different point and line models which are used by utility organisations for determining the positions of spatial features. A number of these models use the relationships between features and some mapping datum. However, the majority use relationships to other features. These relationships are summarised in Table 4.1.

It would appear from Unkles' models that, for utility organisations, a number of different relationships between point and line features are used, whilst few, if any, between area features are necessary. Further, these relationships are related to field measurements and hence the way the position, in the real world, of the particular utility feature was determined.

Local governments, whilst certainly using utility information, also use other information for which these 'surveyed' relationships may not be appropriate. O'Dempsey and Moorhead (1991) also suggest that a number of councils use the 'relative position' technique for positioning utility information. It would seem that further investigation of the use of positional relationships is necessary.

Model Name	**Description**
Bearing and Distance.	The position of the feature has been determined using a distance and bearing (azimuth) from a known point.
Relative Angle and Distance.	Similar to previous except the direction information comes from an angle with respect to a known line.
Measurements from two points.	Position of point is defined by the intersection of either: • Two lines of known distance each from different known points, or • Two lines of known bearing each from different points, or • Two lines of known direction with respect to some reference line(s).
Relative angles from 3 points.	Better known as a resection, the position of the point is determined using the angles of incidence of lines to 3 known points measured from the point of interest. The point's position is the intersection of these lines.
2 Offsets	The position of the point is defined by the intersection of two lines, each at a known offset from separate reference lines
Offset and parallel distance	The position of the point is defined as being a certain distance along a line offset to some reference line from the intersection of that line with some other reference line.
Parallel offset to line string, distance.	Similar to previous except offset reference line, and hence offset line, is not straight.
Distance along line string, offset	Similar to previous except distance is measured along offset reference line rather than offset line itself.

Incident angle from point, offset.	The position of the point is defined as being the intersection of a line offset to some reference line and a line which is at a certain angle to another reference line and passes through some reference feature.
Taut Offset Line String.	A line which is the same shape as some reference line except that it's start and end points lie offset to the start and end points of the reference line. (These offsets may or may not be the same)

Table 4.1 Positional Relationships used in Utility Data Sets. (adapted from Unkles, 1994.)

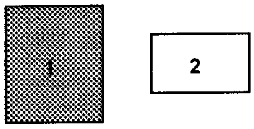
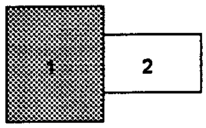
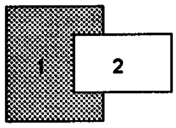
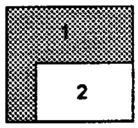
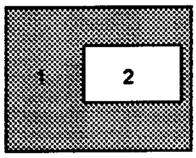
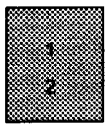
4.2.2 Positional Relationships between Administrative Boundaries

One of the more detailed investigations into positional relationships is that of Driessen and Zwart (1989), who developed a set of 'six mutually exclusive areal relations' which can be used to describe the relationships between parcels, or area features, in a GIS (Table 4.2). These relations were developed using principles from the work by Pullar and Egenhofer (1988) on topological relationships.

The development of these relations was brought about after the authors recognised that, whilst the most common spatial land unit used in GIS is the legal parcel (cadastre), other units such as fiscal (property) and other administrative units are also used. Furthermore, these other land units are often made up of units from other sets or are 'statistically dependent' upon other units. Thus a single property may actually be made of more than one legal parcel.

It was envisaged by Driessen and Zwart that, using these relations, it would be possible to describe the statistical dependence of one cultural parcel (eg. a property) upon other cultural parcels (eg. cadastral parcels). This would then allow for more efficient storage of spatial information as only graphical information for the base units would need to be stored.

One of the defining features of topological relationships is that they are purely qualitative in nature and do not include any reference to quantitative measurements (Egenhofer and Herring, 1994). Thus, given the nature's of some of the positional relationships identified in the previous section, it would seem that positional relationships are not a subset of topological relationships. However, the work of Driessen and Zwart (1989), whilst concerned primarily with topological relations, did identify one important positional relationship. That is, the fact that many administrative boundaries used by society are actually coincident with other boundaries. Thus the relations; 'meet', 'common_bounds' and 'equal' are of interest and may be useful in the local government context.

disjoint Parcels 1 and 2 share no common positional attributes.	
meet Parcels 1 and 2 abut one another yet do not overlap.	
overlap Part of Parcel 2 equals part of 1.	
common_bounds Parcel 2 is contained within 1 and they share common boundaries	
concur Parcel 2 (including boundaries) is contained wholly within 1	
equal Parcels 1 and 2 are equal in size, shape and position.	

<u>Table 4.2 The Relations Between Area Features</u>. Using these 6 relations it is possible to describe all relationships between area features in a GIS (Driessen and Zwart, 1989).

4.2.3 Positional Relationships and Coordinate Geometry

Perhaps the most obvious insight into the types of positional relationships employed by GIS users can be gained by looking to the commercial GIS packages themselves. Many GIS packages provide the user with the ability to use relationships to position new features. In fact Huxhold (1991) suggests that an essential part of any GIS package is software for the translation of survey data (coordinates, bearings, distances, etc) into map information.

The following section looks at the coordinate geometry (COGO) techniques provided by two commercial GIS packages. In particular, those functions which are specifically aimed at allowing the user to position one feature with respect to another are reviewed. Two packages have been chosen to show that, whilst terminology may change, the functionality provided by GIS vendors is similar. In each case, information about the available functionality has been taken from manuals provided with the software.

The first package for investigation, ARC/INFO, is one of the worlds largest selling commercial GIS packages. According to the COGO Users' Guide(ESRI 1991) for this software, the user is provided with a number of techniques for positioning features. These are listed in Table 4.3.

The second GIS package, GenaMap, is one of, if not the most popular systems used by local government in NSW. Users of GenaMap (Genasys, 1995) are provided with a similar set of functions to those provided in ARC/INFO (see Table 4.4).

As the name implies, coordinate geometry techniques allow the user to create features using calculations based upon the coordinates of some base feature and specific measurement details. Thus users are provided with the ability to perform functions such as:

- create points and lines at a particular offset;
- create a point at a known distance and direction;
- create a point at the intersection of two lines;
- create a straight line for a known distance in a known direction;

- create a point using combinations of distances; and
- create a point using combinations of directions.

The fact that both ARC/INFO and GenaMap provide the user with the above COGO techniques shows that the vendors of these packages have recognised the need to be able to use positional relationships. Furthermore, these packages allow the user to use these functions in various combinations. Thus it is possible that complicated positional relationships might be employed to determine the positions of specific features.

Command	**Description**
LAYOUT	Creates a line from a starting point given a specified distance and direction.
CROSS	Creates a point at the intersection of two lines.
LOCATE	Creates a point at the intersection of any combination of two angles, bearings or distances.
RESECT	Creates a point using a three point resection (ie. three angles).
TRILATERATE	Creates a point using a three point trilateration (ie. three distances).
DROPPERPENDICULAR	Creates a point on a line which is perpendicular to a known point.
OFFSET	Creates a point at a known distance perpendicular to a line.
WIDEN	Constructs lines parallel to a selected line (offset)

Table 4.3 COGO Functionality in ARC/INFO. A list of those functions allowing the positioning of one feature using positional relationship provided in the ARC/INFO GIS package (ESRI, 1991).

Command	Description
CGAPOINT	Creates a point from a starting node (point) given a specified distance and azimuth.
CGALINE	Creates a line from a starting node (point) given a specified distance and azimuth.
CGBPOINT	Creates a point from a starting node (point) given a specified distance and bearing.
CGBLINE	Creates a line from a starting node (point) given a specified distance and bearing.
CGDPOINT	Creates a point from a starting node (point) given a specified change (delta) in the x and y coordinates.
CGDLINE	Creates a line from a starting node (point) given a specified change (delta) in the x and y coordinates.
EDMINTERS	Creates a point at the intersection of two lines.

Table 4.4 COGO Functionality in GenaMap. A list of those functions allowing the positioning of one feature using positional relationship provided in the GenaMap GIS package (Genasys, 1995).

4.2.4 Summary

A great number of different types of positional relationship are used within certain areas of the GIS user community. In general these relationships are used to determine the positions of point features, for example:

- Point at 2 Coordinate Differences from reference point.
- Point at Azimuth and Distance from reference point.
- Point at Bearing and Distance from reference point.

- Point at Distance along reference line from reference point.
- Point Offset from reference line.
- Point at Intersection of 2 reference lines.
- Point at Intersection of lines from two known points defined via measurements (ie. 2 distances, 2 bearing, or 2 azimuths).
- Point at intersection of reference line and perpendicular through known point.
- Point at Intersection of 2 lines. Line 1 at angle to reference line through known point and line 2 offset to another reference line.

or line features, for example:

- Line coincident with reference line.
- Line for 2 Coordinate Differences from reference point.
- Line for Azimuth and Distance from reference point.
- Line for Bearing and Distance from reference point.
- Line Offset from reference line.

It is important to recognise that these relationships are either specific measurements or they give a general indication of the position of a feature without allowing for the calculation of an actual position. This occurs when features a placed 'relative' to some other feature. This distinction will be important when trying to maintain a relationship.

Furthermore, it should be noted that, whilst many of these relationships are purposely introduced into databases, others, such as those used for many administrative boundaries, are introduced as a result of the definition of that particular feature.

4.3 Positional Relationships within a Local Government GIS

Given that local governments use many of the data sets used by other GIS users, it is more than reasonable to assume that the positional relationships identified in Section 4.2 will be used within a local government GIS. However, to ensure that a more comprehensive list of possible relationships is achieved, it was necessary to investigate each of the 76 data sets identified in Chapter 3.

The positional relationships used in the creation of a data set were determined by investigating each individual data set and determining how the data are collected or created. For each data set a list of positional relationships used could then be created. This list forms part of the description of each data set in Appendix A and will not be repeated in this section.

Whilst performing this investigation and compiling the results, a number of important discoveries about the use of positional relationships were made. These discoveries will have an impact on the development of a method for managing relationships and hence are discussed below.

As expected, a large number of different positional relationships are used within a local government GIS. Furthermore, the relationships used are not specific to individual data sets. Thus, whilst one council may use one particular relationship to position a certain feature, another council will use a different relationship to position the same feature. For example, in many councils, utility features are positioned using relative positions. That is, the feature is placed relative to some base feature without the use of measurements. In other councils, however, actual measurements are used to position the same features with respect to the same base.

The investigation also revealed that the base to which features might be related is also dependent upon the particular council. Thus, whilst one council might relate the position of Fire Hazard Areas to the Cadastre, others will relate them to features such as Road and/or River Centrelines.

Finally it was found that, in a number of cases, it is possible for one feature to be related to different features in different spatial data sets. Thus the position of a particular asset may be defined by a distance to a cadastral corner and a relationship to a road feature.

As a result of these findings, it can be concluded that any method for managing positional relationships in a local government GIS cannot be data set specific. Rather it is necessary to develop a method whereby all positional relationships can be managed regardless of the data sets involved. Furthermore, it is necessary to be able to manage many different types of positional relationship.

In order to develop a method for managing a relationship it will be necessary to have a greater understanding of the nature of the positional relationships used in local government GIS. That is, it is necessary to investigate the form of the relationships used, the features involved in these relationships and, the ways in which these relationships are employed. The information gained from such an investigation can then be used to develop a system which is able to manage all positional relationships in all situations arising in a local government GIS.

4.4 The Nature of a Positional Relationship

One of the main purposes for this research is to develop a rules base to be used to manage a positional relationship after a positional change has occurred to one of the features involved in that relationship. In order to do this it is necessary to examine the types of positional change that occur in a spatial database with respect to different positional relationships. This examination will take place in Chapter 5, however it is first necessary to identify a number of factors about positional relationships which may also have an effect on the development of this rules base.

The following sections detail three important aspects of the nature of positional relationships identified from the results of an investigation into the relationships used by local government. The first two sections deal with the concepts of relationship class (the purpose for which the relationship exists) and a feature's place in a relationship. It will be shown in Chapter 5 that these two characteristics play important roles in the management of relationships.

The final section introduces a set of fundamental positional relationships. These relationships form the basis for all positional relationships used within a local government GIS.

4.4.1 Positional Relationship Classes

There a number of ways in which positional relationships can be categorised. One example is by the form a relationship takes (eg. bearing and distance, coincidence, offsets, etc.) and will be discussed in Section 4.3.3. Another categorisation method is by the purpose for which the relationship exists. For this thesis this method of categorisation is known as the **class** of a relationship.

In a local government GIS two distinct classes of positional relationships are used. They are:

1. The position of a feature at a particular time, has been determined using either measurements to other features or by being placed relative to some other feature. For this thesis, this class is referred to as a **Measured** Relationship.

2. The position of one feature is defined for all time by its relationship to another feature. Such a relationship class will be referred to as a **Defined** Relationship.

The difference between these two classes, on the surface, appears small. However it plays a important role in determining the different natures of particular relationships.

In the case of a measured positional relationship, the relationship only exists for the purpose of determining the position of one of the related features with respect to the other features in the relationship at the time of measurement. Driessen and Zwart (1989) refer to the two features as being 'statistically independent' as, whilst they are related in the GIS, in the real world they are independent. Examples of this relationship class occur in the utility industry, where the position of certain utilities is determined by measurements to some base feature, usually the cadastre.

In the case of a defined relationship, however, the purpose for the positional relationship is different. In these relationships, the position of the related feature in the real world, is defined by its relationship to some other feature until this definition is changed. At any time, in order to know where the related feature is, it is necessary to know the position of the feature to which it is related, or its 'base'. The two features are referred to as being 'statistically dependent' by Driessen and Zwart, as the position of the related feature is dependent upon the position of its base. Examples of defined relationships are associated with the many administrative boundaries used by the various levels of government. One boundary may be defined as being coincident with a particular base feature (eg. a road centreline).

The importance of this method for categorising positional relationships is that a relationship's class is one of the major factors contributing to how that relationship will be affected by a positional change to a feature involved in the relationship. That is, in some cases, this effect on a relationship of a positional change will be completely dependent upon the purpose for which that relationship exists. The effects of the different types of positional change on different classes of positional relationship will be discussed fully in Chapter 5.

4.4.2 A Feature's Place in a Positional Relationship

Another important aspect of the nature of positional relationships is the concept of a feature's 'place' in that relationship. This concept is important as it also plays a significant role in determining how a relationship will be affected by a positional change to this feature.

In all cases identified from this investigation a positional relationship will be such that the position of one feature in the relationship will, through the relationship, be dependent upon the position of one or more other features. Thus, for each relationship there will exist a 'Slave' feature, which is dependent upon one, or more, 'Master' features. This difference in status, or **place**, of the features involved plays a important role when determining how a particular positional change to one of these features will affect the relationship between them. Once again, this effect will be discussed fully in Chapter 5.

4.4.3 The Fundamental Positional Relationship Types

It is clear, from Section 4.2, that there is a great variety of different positional relationships used within different areas of the GIS user community (eg. bearing and distance, relative position, coincidence, etc). Given that local governments also use many of these data sets, it was suggested in Section 4.2.4 that it would seem reasonable to assume that most, if not all, of these different types of relationships will also be used by local governments in the creation or collection of their spatial data. The investigation into each local government data set confirmed this assumption.

It will be shown in Chapter 5 that the type of positional relationship plays no role in determining how that relationship is affected by a positional change. However, it was noted in Chapter 2 that, whilst maintenance of a relationship does not constitute comprehensive management of that relationship, the management process may require that the relationship be maintained. In order to perform this action correctly it is first necessary to understand that relationship. In particular it is necessary to have knowledge of the type or **form** the relationship takes. That is whether the features involved are related by a bearing and distance relationship or a coincidence relationship or a relative position, etc. Thus it is necessary to have knowledge of every possible type of positional relationship.

A closer examination of each of the different types of positional relationships identified reveals that many of them are, in fact, combinations of one or more fundamental positional relationships. For example, a bearing and distance is in fact a combination of a distance relationship and a bearing relationship. Furthermore, a bearing is actually the direction of a line whose angle of intersection with another line (north-south) is known.

Following is a description of each fundamental positional relationship identified from local government GIS in terms of the related features (ie. points, lines and areas). In each case a diagram and description will be given along with a pseudo-equation representing the form of the relationship. Each of these equations will use the following terminology:

$P_m n$, $L_m n$ or $A_m n$ = the position (location) of the *n*th Master Point, Line or Area feature involved in the relationship.

That is, the positions of the n Master features, m, involved in the relationship, upon which the position of some Slave feature is dependent.

P_s, L_s or A_s = the position of the Slave Point, Line or Area feature.

That is, the position of the Slave feature S which is dependent upon some positional relationship with one or more Master features.

It should be noted that a number of the fundamental positional relationships for point features will not actually allow for the determination of the position of the Slave feature by themselves. Rather the relationship will define a line upon which the feature lies. These relationships can however be used in combination with other relationships in order to determine a unique position. Examples of such combinations will be given later. These lines will be identified using the symbol LP_S.

4.4.3.1 *Relationships Between 2 Point Features*

Distance: The Slave Point P_S lies on the line LP_S which is a circle of radius *d* centred on the Point P_m.

LP_S = dist {*d*:P_m}

where *d* is a known distance

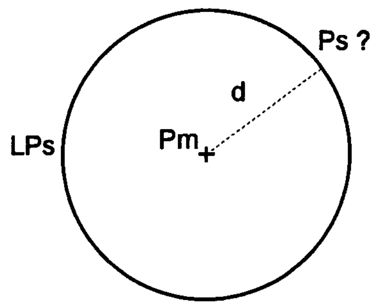


Figure 4.1 The Distance Relationship.

It is clear that this relationship alone will not allow for the determination of the position of a slave point feature. Thus it is necessary to combine it with other positional relationships to determine a unique position.

The one exception to this case occurs when the distance *d* is equal to 0. That is, the master and slave points are coincident. Point coincidence is a very common positional relationship in local government GIS.

A point coincidence occurs when a particular point feature in one data set needs to remain coincident with a point feature in another data set. For example if a council uses different data sets to represent different road classes, it is important to ensure that the different classes of road intersect at the actual, real world, intersections. Similarly, in cases where a council splits pipe network data sets into two sets, one representing pipes and the other fittings, the fittings, which will be point features, should remain coincident with other point features, such as junctions, in the pipe set.

As mentioned previously, for all other cases of a distance (ie. where *d* is greater than zero) it is necessary to use this relationship in conjunction with one or more other relationships in order to determine the position of the slave feature. For example, the use of three distance relationships, referred to as a 3 point trilateration (Figure 4.2), can be used to define a unique position.

3 Point Trilateration: The position of the Slave Point P_S is defined as the intersection of 3 circles of known radii (d_1, d_2, d_3), centred on 3 known points (P_{m1}, P_{m2}, P_{m3}).

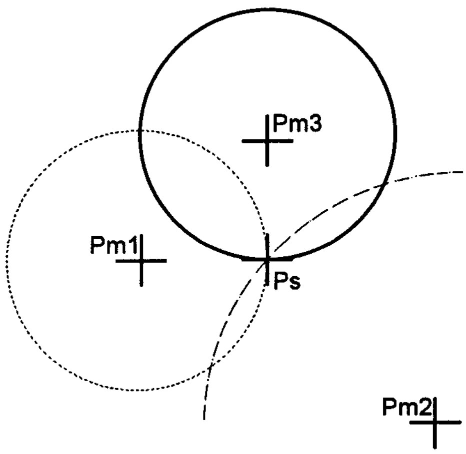


Figure 4.2 Distance Measurements from 3 Points.

Many of the point model relationships identified by Unkles (1994) and discussed in Section 4.2.1 use distance relationships for positioning utility information. These models include: Bearing and Distance, Relative Angle and Distance, and Measurements from 2 Points.

4.4.3.2 Relationships Between 3 Points

Angle To Slave Point: The Slave Point P_s lies on the straight line LP_s which passing through the Master Point P_{m1}. The line LP_s intersects a straight line L_m (between the Point P_{m1} and the Point P_{m2}) at the Point P_{m1} such that the clockwise angle from L_m to L_s θ is known.

LP_s = angle_to $\{\theta:P_{m1},P_{m2}\}$

where θ is the clockwise angle from the line between P_{m1} and P_{m2} to the line L_s

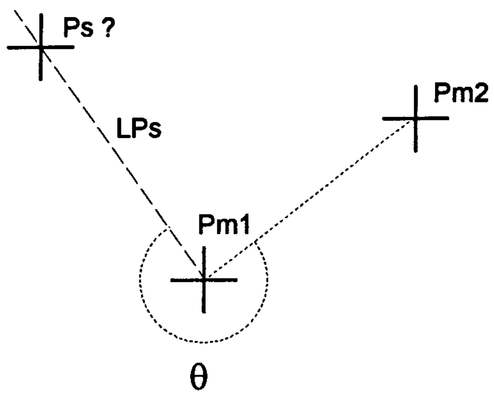


Figure 4.3 Angle to Slave Point.

As with the distance relationship (d > 0), it is not possible to use this relationship alone to determine the position of a slave point. However, in combination with the distance relationship, it is one of the most important positional relationships used by councils. This importance is due to the fact that one of the most common forms of this relationship is the 'bearing'. That is, the angle θ, is an angle with respect to north (see Figure 4.4).

Bearing and Distance: the position of the Slave Point P_S is defined by the intersection of a circle of known radius *d* centred on the Point P_{m1} and a line intersecting (at an angle θ) a straight line passing through the points P_{m1} and P_{m2} (north) at P_{m1}.

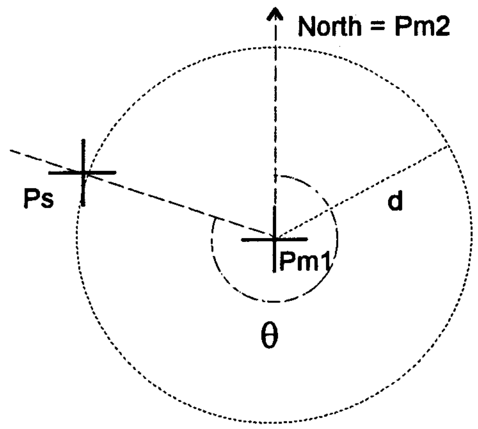


Figure 4.4 Bearing and Distance.

Angle At Slave Point: the position of the Slave Point P_S lies on the line LPs such that, at all times, the clockwise angle θ between a straight line from P_S to the Master Point P_{m1} and a straight line from P_S to the Master Point P_{m2} remains constant.

LP_S = angle_at {θ:P_{m1},P_{m2}}

where θ is the clockwise angle from the line P_S-P_{m1} to the line P_S-P_{m2}

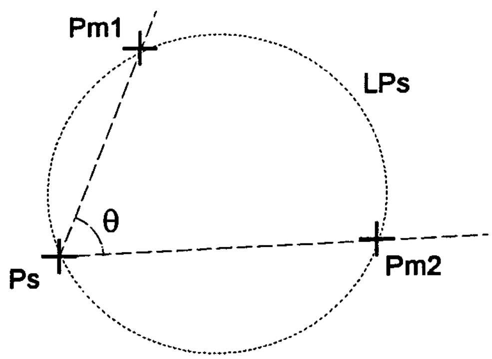


Figure 4.5 Known Angle at Slave Point.

The Angle At relationship is yet another positional relationship which cannot be used alone to determine the position of a slave point. This relationship can however be used with one or two distance relationships or, more commonly, used in tandem with a similar relationship for which one of the two straight lines is common. Such a combination is commonly referred to as a 3 point resection (Figure 4.6).

3 Point Resection: The position of the Slave Point P_s is defined by the intersection of 3 circles. The first circle is defined such that the clockwise angle θ_1 between a straight line from P_s to the Master Point P_{m1} and a straight line from P_s to the Point P_{m2} remains constant. The second circle is defined such that the clockwise angle θ_2 between a straight line from P_s to P_{m2} and a straight line from P_s to the Point P_{m3} remains constant. The final circle is defined such that the clockwise angle θ_3 (= θ_1 + θ_2) between a straight line from P_s to P_{m1} and a straight line from P_s to P_{m3} remains constant.

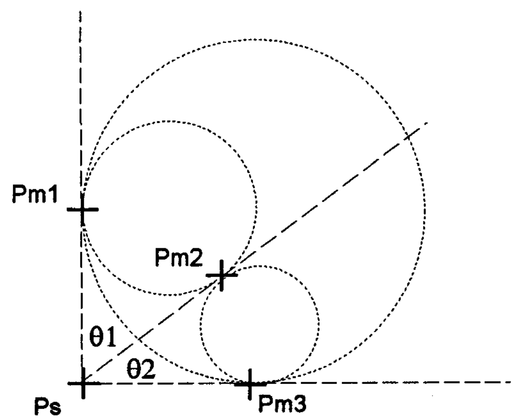


Figure 4.6 3-Point Resection.

4.4.3.3 Relationships Between a Point, and a Point and a Line Feature

Distance Along a Line: The position of the Slave Point P_s is defined as being a point lying on the Master Line L_m a distance *d* along that line from the Master Point P_m

P_s = dist_line $\{d{:}P_m, L_m\}$

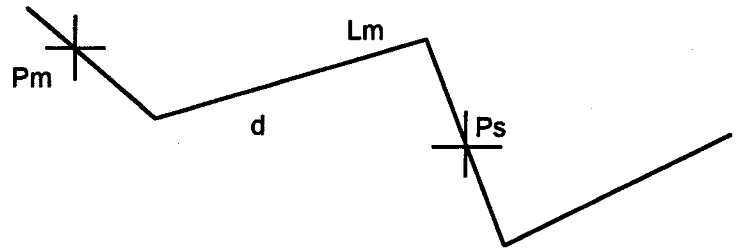


Figure 4.5 Distance Along a Line.

Unlike the previous relationships, it is possible to determine a unique position using a distance from a point along a line. Examples of the use of this relationship occur where the positions of roadside features (ie road assets) have been determined simply using the distance of the feature along the road centreline from a known point (eg. an intersection). Similar examples occur in the positioning of features in utility networks.

Whilst this positional relationship will allow for the determination of a unique position, it can be used in combination with other relationships as well. Thus it can be used as a part of Unkles (1994) 'Parallel offset to line string and distance' and 'Distance along line string, offset' relationships.

It should be noted that, in order for this relationship to be used, it is necessary that both slave and master point features are coincident with the line. Direction along the line (ie from the master point) is determined by the direction of the line itself. This direction is implied from its topological definition (ie. the line is between a 'from' node and 'to' node). Thus a negative value for *d* will imply that the slave point lies towards the tail (the 'from' node) of the line from the master point.

4.4.3.4 *Relationships Between a Point and A Line*

Point Offset: The Slave Point P_S lies on the line LP_S which lies parallel to and a distance *d* from the Master Line L_m

LP_S = offset_point {d:L_m}

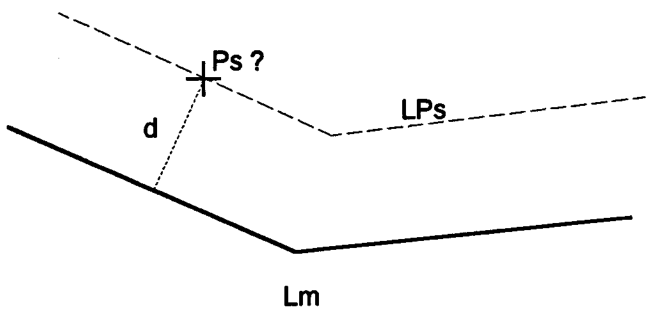


Figure 4.6 Offset between a Point and a Line.

As with the 'Distance Along a Line' relationship, it is necessary to define some convention for determining the direction of the offset (left or right of the line). For consistency it seems wise to use the same approach as used previously. That is to use the topologically implied direction of the line. In this way, offsets to the left, when travelling towards the head of the line (towards the 'to' node), can be defined as being negative.

Once again, this is another positional relationship which cannot be used alone to determine a unique position for the slave point. It is however regularly used in conjunction with other relationships such as 'Distance Along a Line' or with another point offset relationship as shown in Figure 4.7

2 Point Offsets: The position of the Slave Point P_S is defined as the intersection of 2 lines (LP_{S1} and LP_{S2}), one of which runs parallel to the line L_{m1} at a distance d_1 and the other runs parallel to the line L_{m2} at a distance d_2.

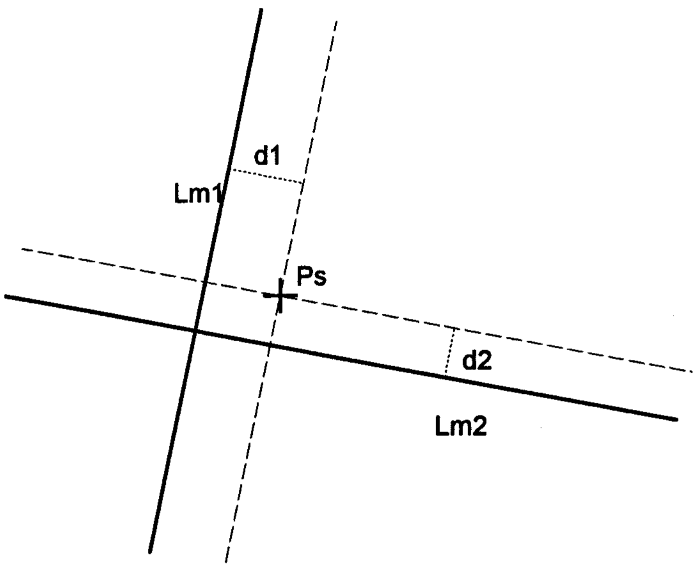


Figure 4.7 Two Point Offset Relationships.

4.4.3.5 *Relationships Between a Point and 2 Lines*

Intersection: The position of the Slave Point P_s is defined as the intersection of the Master Lines L_{m1} and L_{m2}.

P_s = int (L_{m1},L_{m2})

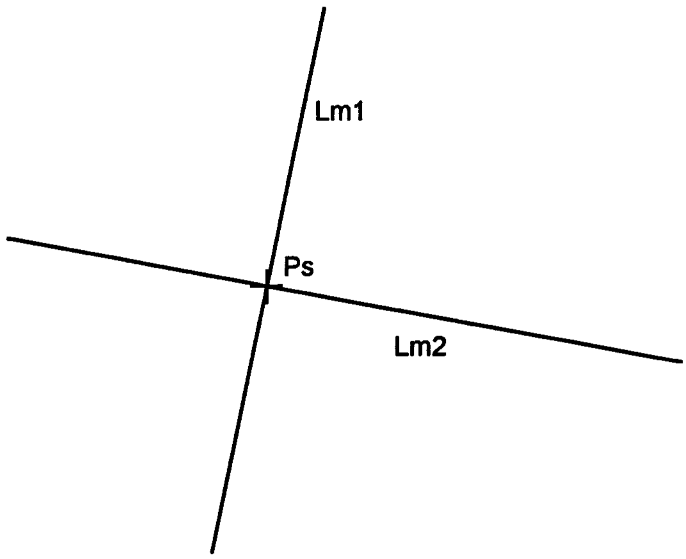


Figure 4.8 Intersection of Two Lines.

Coincidence with the intersection of two line features is another common relationship used by local governments. Its use is found in the definition of the position of features in administrative boundary data sets as well as in the positioning of utility features.

As with a number of other positional relationships an intersection can be used alone to define the position of a feature. However, its most common use occurs in conjunction with other relationships. A number of the combinations of positional relationships already described (eg. Bearing and Distance, 3 Point Trilateration and 2 Point Offsets) involve the use of an intersection relationship to determine the position of the slave point.

There exists one difficulty with the definition of this relationship. This occurs when two master lines intersect more than once. This will occur, for example, if a section of road centreline crosses the same river or stream in more than one place (Figure 4.9). In these cases, it is obvious that a unique position for the slave point will not be found using the intersection relationship alone. Thus, it is necessary to be able to uniquely identify each intersection point.

In order to do this some other relationship can be used in combination with the intersection, or each intersection point can be given a unique identifier based upon its position along one of the intersecting lines. Thus, using the implied direction of one of the master lines, the first intersection point would be identified as 1, the second, 2, and so on. The equation for the intersection relationship thus becomes:

$$P_s = \text{int}\{i : L_{m1}, L_{m2}\}$$

where i indicates the *ith* intersection of the line L_{m1} with the line L_{m2}

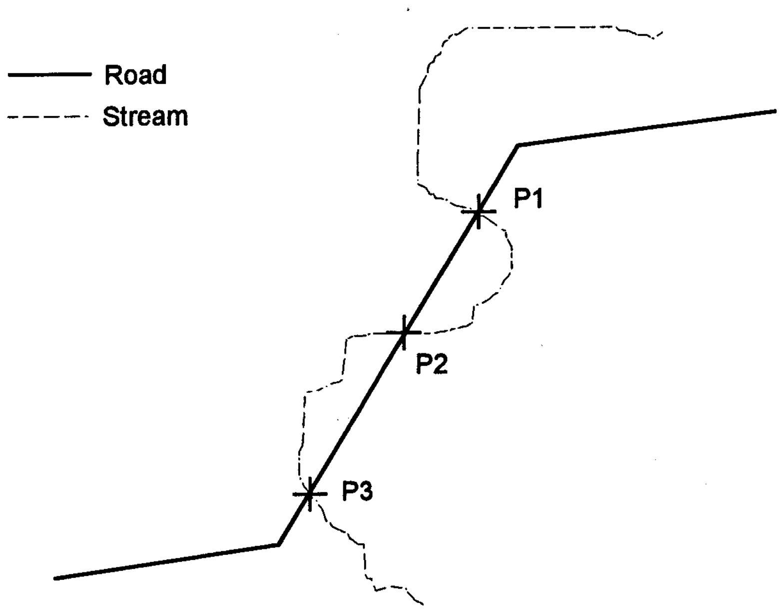


Figure 4.9 2 Lines intersecting more than once.

4.4.3.6 Relationships Between 2 Lines

Line Offset: The Slave Line L_s is defined as being a line parallel to and at a square distance *d* from the Master Line L_m.

L_s = offset_line {*d*:L_m}

where *d* is a known distance

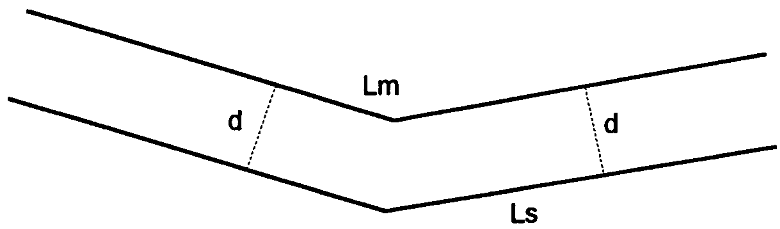


Figure 4.10 Offset between 2 Lines.

This is, by far, the most common relationship used within a local government GIS. Its popularity is due mainly to one special case. That is, when the offset distance *d* is equal to 0. The two lines are coincident.

Almost half of the data sets identified and investigated by this project use some form of coincidence relationship in order to determine the position of certain features within them. These data sets are predominantly administrative boundaries such as properties, electorates, local government areas, etc, however other types of data also use coincidence.

The reason for the extensive use of coincidence is due to the fact that many of these data sets are actually derived directly from one or more other data sets. That is, the position of the line features in these data sets are defined to be coincident with line features in one or more other data sets. For example, property boundaries are defined to be coincident with cadastral boundaries and electoral boundaries are defined to be coincident with road centrelines, cadastral boundaries, local government areas, etc. Driessen and Zwart (1989) recognised the importance of coincidence when developing their set of fundamental relationships between area features discussed in Section 4.2.2. Hence they developed the **meet**, **common_bounds** and **equality** relationships.

However, whilst these basic relationships are useful for describing the relationship between two area features, such as the relationship between the boundaries of a property and the cadastre, they do not allow for cases where the boundaries of one area feature are coincident with features in more than one other data set (eg an electoral boundary). In order to achieve this it is actually necessary to relate the line features in each of the data sets involved, rather than the area features. This is done by defining the boundary of one area to be at an offset of 0 to another.

Whilst coincidence is the most common form of the offset relationship, relationships where the offset distance is greater than 0 also exist. Examples of this occur in the utility data sets and also in the definition of boundaries such as 'building lines' and 'easements'. As with point offsets, it is necessary to be able to define which side of the master line the slave line occurs. It is suggested that this be done by having positive and negative offsets (eg. offset to the left is negative) and using the implied direction of the master line.

4.4.3.7 Relative Position

Positional relationships in the relative position category are different from those described previously. Whilst most of the relationships discussed so far involve specific measurements, a relative position relationship is not specific at all. Rather, it occurs when the user wishes to place one feature in a position relative to another feature (eg a point inside an area). That is, no measured or calculated relationships exist. Rather it is the relative position of one feature with respect to the other that is important. An example is shown in Figure 4.11.

Relative position relationships are generally used in situations where the user needs to be able show the relative positions of features but does not have, or does not wish to use, specific measurement details.

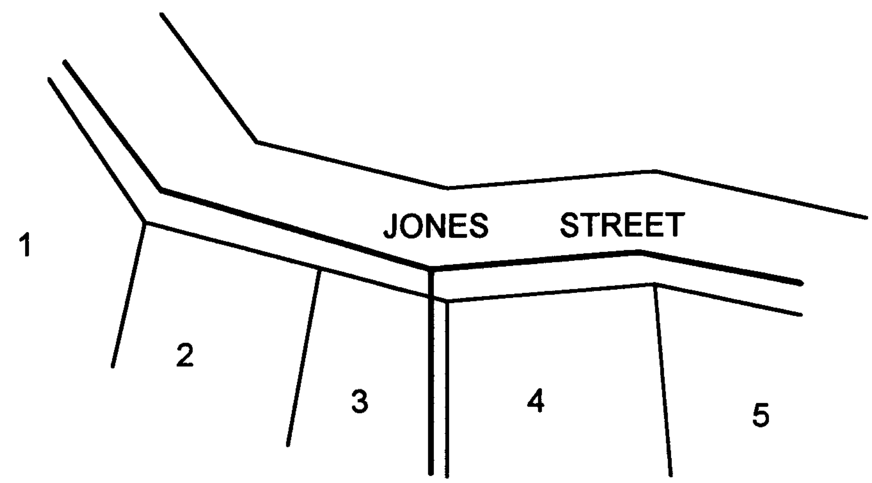


Figure 4.11 Relative Position. The utility feature (bold) has not been positioned using measurement data. Rather it has been positioned 'relative' to the cadastre (thin). Thus, the only knowledge about the position of the utility information is which polygon features it passes through (eg. Jones Street and Parcel 3) and which part of these polygons (eg. which side of the street).

There are a number of possible cases for a relative position relationship.

a) Point - Line

$P_s \Leftrightarrow$ relpos $\{L_m\}$

In this particular case a point feature is positioned on one particular side of a line feature (ie left or right of the line). That is, the only positional information known about the slave point with respect to the master line are the relative positions of the two features. The absolute position of the point feature with respect to the line is either not known or has been determined in using some other positional relationship. The purpose of the relationship is simply to define which side of the line the point is located.

A good example of the use of this relationship occurs in data sets where two distance relationships have been used to determine the position of a point as shown in Figure 4.12.

2 Distances and a Relative Position: The position of the Slave Point P_s is defined as the intersection of 2 circles of known radii (d_1, d_2) centred on the 2 Master Points P_{m1} and P_{m2}, and lying to the right of the straight line between P_{m1} and P_{m2}.

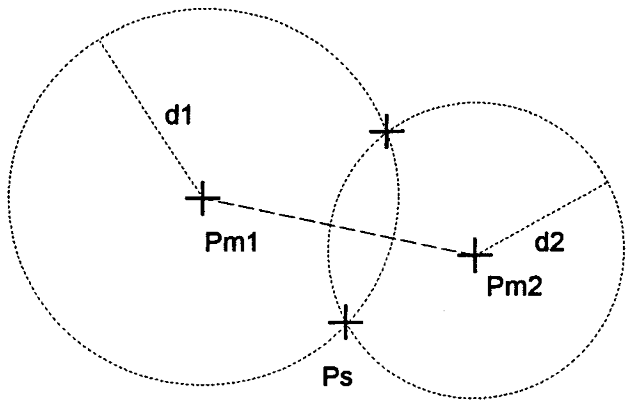


Figure 4.12 Two Distances and a Relative Position.

b) Point - Area

$$P_s \Leftrightarrow \text{relpos}\ \{A_m\}$$

In a number of older commercial GIS packages, the occurrence of the 'point in area' relative position is common due to the use of 'paracentroids'. A paracentroid data set is a set of point features which have an associated set of polygon features. The paracentroid is used as a type of pseudo identifier against which information about the associated polygon is stored (Lebens, 1995). This relationship between the point and polygon features means that, should the polygon undergo any form of positional change (to be discussed in Chapter 5), any associated paracentroid may also require updating. It is thus necessary to ensure that each paracentroid is closely related to its associated polygon.

c) Line - Area

$$L_s \Leftrightarrow \text{relpos}\ \{A_m\}$$

The line/area relative position relationship is similar to the point/area relative position and will not be discussed further, except to say that both relationship types are used in conjunction for many local government GIS.

The use of relative position relationships for positioning spatial data has been recognised by a number of authors and was discussed briefly in Section 4.2.1. Clatworthy (1994 a, b) refers to 'inaccurate utility information' when describing a method to maintain relative position relationships after a certain form of positional change has occurred to associated spatial databases (see Chapters 4 and 5). This terminology recognises the fact that the use of this method for positioning data results in positions of unknown accuracy and hence should be treated as such.

O'Dempsey and Moorhead (1991) also recognise that councils need to position utility services 'in the correct relative position to the cadastral database (at the expense of absolute positional accuracy)'. This need arises from the fact that, often, the master and slave information come from different sources at different accuracies. This means that the direct integration of the two data sets is impossible without resulting in features being placed in incorrect relative positions.

It can therefore be seen that the Relative Position relationships (point/line, point/area and line/area) are very important to local government. This importance is so great that a number of methods to maintain these relationships alone have been developed. A number of these methods will be discussed in Chapter 6.

4.4.3.8 Relationships between Data Sets.

A number of the data sets used by councils are created using information in other data sets via certain mathematical models. For example:

- Slopes can be related to contours via a Digital Elevation Model (DEM) (Burrough, 1993).
- Land slip areas are determined using soil and slope information via certain other models.
- Areas where the risk of flood inundation is high are determined using yet other models based upon natural drainage, rainfall and contour information.

In each of the above cases the models used do not involve the use of relationships between specific features. Rather, they use information over specific areas within the data set to calculate the position of some other feature. Thus it would seem that it is the data sets themselves which are related, via these models, rather than individual features.

Whilst this type of relationship is different from those discussed previously, it is important to recognise its existence, as a number of data sets used by local governments fall into this category. In general, these data sets are environmentally based (eg. soil types, slopes, areas of environmental significance, etc.). Due to the increasing environmental awareness of the community, councils are requiring more accurate, up to date environmental information. Thus, the management of positional relationships between these data sets is important.

4.5 Summary

A positional relationship is any relationship, used by a GIS operator, to place one feature in a spatial data set with respect to one or more other features. Unlike other spatial relationships, such as topological relationships, they are introduced into a GIS by the user.

Positional relationships play an important role in the creation of many of the spatial data sets used by local governments. This chapter investigated the nature of these relationships both in terms of which relationships are used and why they are used. The purpose for this investigation was to gain a greater understanding of positional relationships in order to develop methods for managing them in a local government GIS.

The investigation started by looking at the positional relationships used in other fields of the GIS community. As a result, a variety of different types of relationship were found. These included a number of relationships involving specific measurements and some that do not. Each of the many data sets identified in Chapter 3 as being of interest to local government were then examined to determine which positional relationships were used in their creation.

The results of this investigation found that a number of factors were involved in the use of positional relationships by local governments. These factors are:

1. It was found that two distinct classes of positional relationships are used. They are:

   Measured Relationships - the position of the slave feature within the spatial data set was determined using some relationship to the master feature(s) measured at a particular time. Otherwise the features are unrelated, and

   Defined Relationships - the positional relationship is used to define the position of the slave feature in the real world at all times. The Master and Slave features are very much related.

   It will be seen that the class of a relationship plays an important role when determining the effect of a positional change to the features involved in the relationship.

2. A number of fundamental positional relationship types were identified. These relationships can be used singularly, or in combination, to describe each of positional relationships used by local governments.

3. It was discovered that, whilst many relationships occur between spatial features, in a number of special cases, the relationship occurs between whole data sets. These relationships occur when mathematical models are used to create a data set.

Using the results of this investigation it will be possible to develop methods to manage positional relationships during the life of a local government GIS. However, before this can be done, it is necessary to investigate the types of positional changes that take place within a spatial database, the way these changes are integrated into a GIS and the effect these changes have upon positional relationships. This will be done in the Chapter 5.

5. Positional Changes Within a Local Government GIS

5.1 Introduction

Whilst the positional relationships identified in Chapter 4 may be used to position point, line and polygon features in local government spatial databases, the GIS packages used by most councils do not store this information. Rather, they convert relationship information into sets of cartesian coordinates representing the positions of features. That is, once the relationship has been used to determine the position of a particular feature, this positional relationship information is discarded.

Coordinates are used because they are a simple, easily stored, easily manipulated, homogeneous data set. However, in many cases, they do not represent the way in which the data was captured. Furthermore, their use assumes that the position of the feature is known perfectly and will remain unchanged for the life of the spatial database.

In a perfect world, such an assumption will not cause problems. In the real world, however, this assumption has been, and continues to be, the cause of a great deal of concern to users of spatial information. The problem with assuming that the positions of features are known perfectly and will not change, is that, for a number of GIS users and especially local government, it is incorrect. In Chapter 3, it was noted that a number of the data sets used by councils are dynamic. That is, the positions of certain spatial features within these data sets are undergoing constant change. These changes occur because of changes in the real world or changes to the original positional information used to represent the feature. It was also noted in Chapter 3 that the Cadastre, which is one of the most important data sets used by local government, is also one of the most dynamic data sets.

A number of authors have recognised that a change to the position of one feature may have a profound effect on the position of another feature due to the fact that a positional relationship exists between them (Hebblethwaite 1989, Unkles 1992, Corson-Rikert 1988 and Wan and Williamson 1994a). They point out that the maintenance of such relationships is important for maintaining the spatial integrity of the GIS. In Chapter 4 it was revealed that a number of the spatial data sets used by local government are constructed entirely using positional relationships. Hence, in order to maintain the spatial integrity of local government databases, it may be necessary to be able to maintain these relationships.

Chapter 2 reviewed a number of techniques proposed for maintaining positional relationships. However, in each case the development of these techniques has tended to concentrate on specific data sets and certain types of positional change. Clatworthy (1994a,b), Unkles (1992) and Wan and Williamson (1994b) all developed systems for maintaining relationships between some base layer (usually the Cadastre) and various utility data sets (eg. water, sewer, gas, electricity). Corson-Rikert (1988) identified the need to ensure that coincident features remain coincident after a change to one of the affected features.

Unfortunately, these techniques only address specific cases and do not lend themselves to solving the problems caused by positional changes in a more general case, such as local government, or for a generic set of GIS procedures. By concentrating on these specific situations, the authors have been able to ignore the fact that positional relationships have varying, and somewhat dynamic, natures themselves. These natures were discussed in Chapter 4. Furthermore, different types of positional changes will have different effects upon these relationships depending upon this nature. Therefore the correct action to take with respect to any positional relationship affected by a positional change is not necessarily to maintain that relationship. Thus, before it is possible to develop methods for managing positional relationships in a local government GIS, it is necessary to understand these relationships and the effect different positional changes will have upon them.

This chapter is divided into two sections. Firstly, an investigation of the processes of positional change to features in a spatial database is performed. This investigation looks at the nature of these changes and their effect upon positional relationships. Particular attention is given to the role the nature of a relationship plays in determining this effect.

Secondly, the methods by which positional changes are integrated into a user's GIS are examined. It will be seen that the methods used have importance consequences for the development of a method to manage positional relationships.

5.2 Positional Change in a Spatial Database

To assume that the position of a spatial feature will remain unchanged for the life of a spatial database is incorrect and unwise. Many of the features, represented in local government GIS, undergo constant positional change. These changes take a number of forms and occur for a number of reasons. In each case however, in order to ensure the integrity of the spatial database, it is necessary to ensure that the database is a true representation of the real world. That is, it is necessary to make these changes within the GIS.

Positional changes in a spatial database are generally divided into two categories:

1. The position of the feature has changed in the real world.

   Such a change will occur if a feature is moved, created or ceases to exist, in the real world. In each case, it is necessary to reflect this change in the spatial database in order to maintain its **currency**. If this is not done the information in the GIS will fail to represent reality.

   Such a change is commonly referred to as an **update** (Masters 1988, Baker and Paxton 1994).

2. New information about the original position of the feature has been obtained.

   In this case, the position of the feature, in reality, has not changed at all. Rather, the set of coordinates used to represent the position of the feature in the GIS has been replaced by a new set of coordinates. This new information may have a number of sources and may, or may not, be more accurate than the original information, depending upon its source.

   The inclusion of such information in a GIS is commonly referred to as an **upgrade** (Masters 1988, Baker and Paxton 1994).

Both types of positional change occur in some spatial databases regularly. In both cases the change will result in a change to the positional representation of features within the GIS. In turn, any positional relationships that may have existed between these features and other features will be affected in some way.

However, this effect will differ greatly depending upon the type of change, the relationship class (Section 4.3.1) and the affected feature's place within the relationship (Section 4.3.2). It is therefore important to understand the differences between updates and upgrades and the effects these types of positional change have upon the different classes of positional relationships.

5.2.1 Updates

The process of updating is aimed at maintaining the currency of a spatial database. As changes occur, in the real world, to features represented within a particular data set, it is necessary to make these same changes to the digital information. This is done to ensure that the data set remains a true representation of reality. Failure to update a data set will mean that the data set will, over time, become less representative of reality and hence less useful. Thus maintenance of a database through updating is an important task.

The frequency with which it will be necessary to update a particular data set is dependent upon the nature of the data themselves. For some data sets the need to perform updates may occur irregularly, if ever, whilst for others it will be a constant process.

In order to understand the effect of updating upon positional relationships it is first necessary to understand how the process of updating is performed. The following section details the typical procedures used to update a large spatial data set. Specifically the update process as it is carried out by the NSW Land Information Centre (LIC) for the Digital Cadastral DataBase (DCDB) will be reviewed. This example has been chosen as a large number of councils in NSW use the LIC's DCDB. The DCDB was described in Section 3.5.1.

5.2.1.1 The Updating Process

The cadastre in NSW is a dynamic data set. In 1988 the Land Titles Office (LTO), which is responsible for the registration of land titles in NSW, reported that it was registering approximately 30 changes per day to the cadastral framework (LTO, 1988). Thus the process of maintaining a digital copy of the cadastre, such as the DCDB, is one of constant updates. However, despite the need for frequent updating, this process has never been fully automated by the LIC. That is, the process is performed manually.

The process used by the LIC for updating the DCDB is as follows:

a. Information about changes to the cadastre is collected from relevant sources.

   In order to update the DCDB, the LIC receives information about changes to the cadastre from a number of organisations.

   i. The main source is the LTO which provides details of all changes to the cadastre registered by it. This information accounts for approximately 500-600 changes per week (Carr, 1994).

   ii. Information about changes to the DCDB is also taken from the State and Federal Government gazettes. These list changes to such things as the boundaries of National Parks and State Forests (Baker and Paxton, 1994).

   iii. Finally, many local and state government bodies provide information about changes to the DCDB. In the case of local government, these changes are generally corrections based upon that particular council's records. State Government bodies provide departmental plans about cadastral changes for which it is responsible (eg. the creation of easements).

   In total the updating section processes approximately 1200 changes to the DCDB per week (Carr, 1994). These changes range from simple identifier changes through to the addition of complex, multi-lot subdivisions.

b. For each individual change, the particular GIS map sheet containing the feature to be updated is removed from the 'master' data storage area. Other operators are therefore prevented from updating the same map sheet.

c. The area to be updated is located within this map sheet and the new information (if it is in hardcopy form) digitised.

   Digitisation of the new information is performed in one of two ways. Firstly, it can be directly added to the base (via COGO entry). Secondly, a new map (using COGO or digitising tablets) can be created and this map can be added to the existing data.

In this second case, once the new data has been entered, the new plan is laid over the base and then rotated and shifted to find a 'best fit' to the base (The LIC has developed a number of automatic routines for finding the best fit for new plans). Once this best fit has been found, minor adjustments are made to both the base **and the new plan** to ensure that the resulting representation of the cadastre is correct.

This method of update originated from the 'let in' procedures used during the original cadastral data capture process (LIC, 1994a). It is maintained to ensure that updating remains as efficient as possible. It also allows for the accuracy of the DCDB to be maintained.

In some cases the best fit for the new plan will be unacceptable. This will generally be due to inaccuracies in the base. In these cases one of two options is taken.

i. The surrounding base is investigated until the problem is found. This is process is either performed by the LIC or, the problem data are returned to their source to be investigated. As the problem may not be in the immediate vicinity of the update in question, this may be a time consuming task. Thus, in many cases a more expedient solution is used.

ii. The new data are digitised, as above, and an affine transformation is used to "rubber-sheet" the data to fit the base. Whilst the first option is obviously the best, this second option is fast and time efficient. It does however completely destroy any inherent accuracy in the new data.

d. Once the graphics and identifiers have undergone the required changes a number of quality control procedures are undertaken. These include ensuring that:

i. all polygons have identifiers and these identifiers appear in a relational database of all DCDB identifiers.

ii. all other LIC data sets which have features coincident with the cadastre have been updated (if necessary).

iii. the map sheet is topologically clean.

Once an update is complete, information is entered into another relational database to indicate which polygons have been updated, the type of update (identifier change or subdivision) and the time and date of the change. This database is used for propagating these changes to the LIC's clients. At the time a set of changes is to be supplied to a client, the database is interrogated and only those polygons which have undergone some change since the last supply of data are provided.

In 1994 the updating process (ie. from receiving information of a change to completion of the update) took approximately 5-7 days.

The DCDB is a representation of the cadastre and is by no means survey accurate. As mentioned in Section 3.5.1.1, the accuracy standard for the DCDB is derived directly from that used for the source mapping. It is the LIC's policy to maintain the DCDB at this accuracy level. There is no attempt made within the update process, to use the inherent accuracy of new information to improve the accuracy of the DCDB.

It has been argued that the LIC's method of updating actually does have the effect of improving the accuracy of the DCDB (Baker and Paxton 1994, Wan and Williamson 1995). This is because every attempt is made to prevent distortion of new data when merging it with the base. (It should be noted that despite this claim, distortion of new information does occur in some cases.) However, whilst this update method may maintain the internal accuracy of new data, it will not improve the absolute positional accuracy of the DCDB with respect to the NSW state mapping grid (ISG). This is because, in order to find a best fit to the base for new information, the new information is rotated and shifted. As a result, any information about the relationship of this information to the ISG is lost.

As well as the absolute position information being lost, any knowledge about the accuracy of the new data is lost as well. The only accuracy information associated with the present DCDB is that given by the accuracy codes mentioned in Section 3.5.1.1. Information about the accuracy of new data is not used or stored in any way. As further updates take place, the accuracy of previously updated sections will be assumed to be that of the original source data. Thus, it is conceivable that a more accurate section of the DCDB will be distorted to fit information of lower accuracy.

This section has shown that updating of the LIC's DCDB is a complex process. However, variations of this same process are used to maintain many spatial databases, including many of those used by a number of local governments.

5.2.1.2 Updating and Positional Relationships

It has been mentioned a number of times that an update will be necessary if the position of a feature, represented in the spatial database, changes in the real world. This will occur if the feature has been moved or has ceased to exist. An example of an update is shown in Figure 5.1. In this example, the Cadastre, to which the Water Main and the Building Line are related, is updated such that the distance between the lines a-a' and b-b' is widened by 5m.

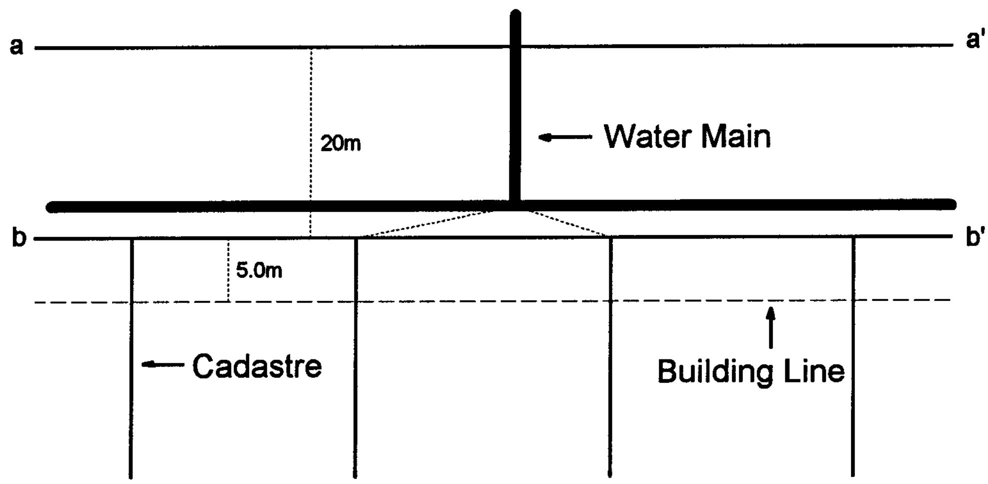


Figure 5.1a. Updates (Before the Update). The cadastre (full line) is the base to which both the water main (bold) and the building line (dashed) have been related by positional relationships. The water main is related to the cadastre by measurements, whilst the position of the building line is defined as being 5.0m offset from the cadastre.

The effect of an update on a positional relationship is very much dependent upon the class of that relationship. In the case of measured relationships, the positions of the features involved are independent. Hence, a change to one of these features will not affect the positions of other features. In these cases the relationship was only used to determine the real world position of one feature with respect to the others at a particular time. Therefore, after an update a measured positional relationship is no longer valid.

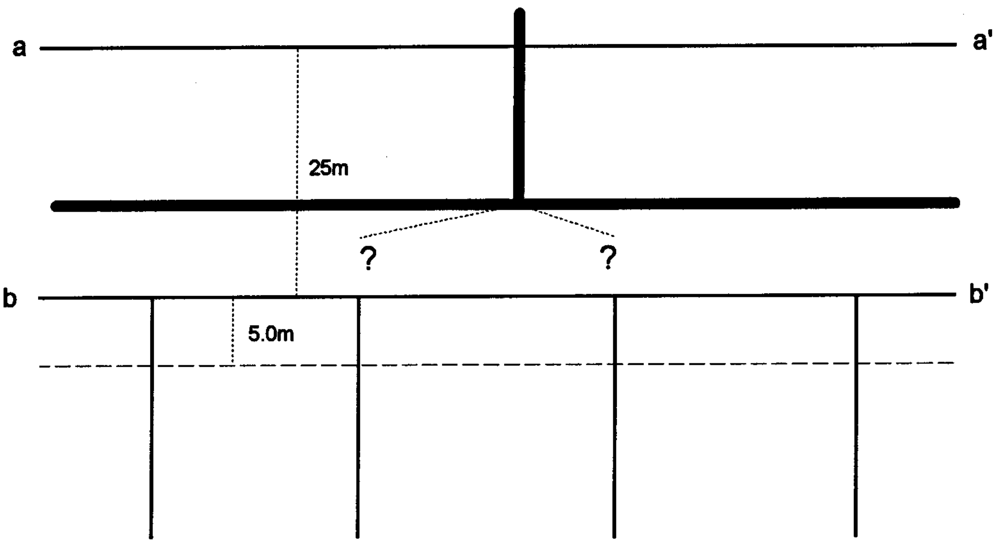


Figure 5.1b. Updates (After the Update). Due to the different relationship classes, the update to the cadastre has affected the two related features in different ways. The building line has also been updated in order to maintain the 5.0m offset requirement. The water main however, does not require updating as its relationship to the cadastre was used simply to determine its original position.

Thus, in the example in Figure 5.1, the position of the Water Main had originally been determined from two relationships to points on the Cadastre. As these are measured positional relationships, the update to the cadastre will have no effect upon the position of the Water Main. The result of the update upon these positional relationships, is that they have become invalid.

For features involved in defined relationships however, the impact of an update will be different. In these cases the result of an update to the base feature(s) will be dependent upon exactly what happened to that feature in reality.

In the case of defined positional relationships, the position of the related feature is defined at all times by its relationship to one or more base features. Thus, when a base feature is moved, it may actually be necessary to perform a similar move to the related feature as the relationship may still be valid. It is therefore necessary to ensure that the relationship is maintained.

For updates where the base feature has ceased to exist, however, two possibilities exist. Firstly, the relationship may become invalid and the related feature will continue to exist independent of any relationship. Secondly, it may be necessary to define a new relationship for the position of the related feature.

In the example in Figure 5.1, the Building Line is defined as being offset 5.0m from the Cadastre. The update, however has caused the feature to which the Building Line was related to be moved. In order to ensure the spatial integrity of the GIS, it is necessary to perform a similar move to the Building Line in order to maintain the offset requirement.

Thus the effect of an update upon a positional relationship is dependent upon the relationship class and, to some extent, the nature of the change that has caused the need for the update. The effects of updates on different classes of positional relationships are summarised in Table 5.1.

Form of Update	**Relationship Class**	**Affect on Positional Relationship**
Moved	Measured	Relationship becomes invalid.
	Defined	Relationship may need to be maintained.
Deleted	Measured	Relationship becomes invalid.
	Defined	Relationship becomes invalid. A new relationship may be needed.

Table 5.1. Effect of an Update to a Base Feature on a Positional Relationship. The effect of the update is dependent upon the relationship class.

In the examples used so far, the updated feature has been a master feature (ie. the base feature). It is also necessary to look at the effects upon a positional relationship in cases where the update occurs to a slave feature (ie. the feature related to the base feature).

In cases where an update occurs to a slave feature involved in a measured relationship, the effect of the update will be the same as that for updated master features. That is, the relationship will cease to exist. This result is obvious as the act of performing the update implies that the slave feature has been moved in reality.

However, in cases where the updated slave feature is involved in a defined relationship, the result is different from that for updated master features. The act of updating the feature implies that the definition of the position of that feature has been changed. That is, the slave feature no longer exists or its position has been redefined with respect to some other feature. In this case, the positional relationship also becomes invalid.

The effects upon different classes of positional relationship of updates to the slave feature in such relationships are summarised in Table 5.2.

Form of Update	**Relationship Class**	**Affect on Positional Relationship**
Moved	Measured	Relationship becomes invalid.
	Defined	Relationship becomes invalid
Deleted	Measured	Relationship becomes invalid.
	Defined	Relationship becomes invalid.

Table 5.2. Effect of an Update to a Related Feature on a Positional Relationship. The effect of the update, whilst still dependent upon the relationship class, is different from that for updated base features.

It has been shown that both a relationship's class and the place the updated feature holds within that relationship, play an important role in determining the effect of an update upon a positional relationship. It is important to note, however that the form of the positional relationship (Section 4.3.3) plays no role in determining this effect. That is, the effect of an update to a feature involved in a positional relationship is not dependent upon the form of the relationship. Thus a relative position relationship and a distance relationship will be affected by an update in the same way if the class of both relationships is the same and the place of the affected feature with the relationship is identical. The fact that the effect of an update is independent of relationship form will play an important role in developing a method for managing positional relationships.

5.2.2 Upgrading

The process of updating spatial databases is a reasonably controlled process. That is, the user has the ability to control when and how an update is made to a database. Upgrading, on the other hand is, in some forms, much less controllable. This type of positional change can occur for a number of reasons.

Upgrading of a spatial feature occurs when the position of that feature in the spatial database is changed without there having been a corresponding change in the real world. This can occur for a number of reasons, however the most common source occurs as a by-product of the updating process. Furthermore, the resultant effect upon positional relationships of an upgrade is different from that of updates. The following section looks at both the processes which lead to a spatial database being upgraded and the effects these upgrades have upon positional relationships.

5.2.2.1 The Processes of Upgrading

As mentioned previously, the most common source of upgrades is as a by-product of the updating process. This will occur in two ways, both of which will be discussed in detail.

The first source of upgrades as the result of an update occurs in situations where original data, not actually affected by an update, are adjusted to fit updated information. Section 5.2.1.1 revealed that the need to perform such an adjustment occurs because, except in the case of data of the highest accuracy, new and old data will rarely match. Thus, whilst new information 'should' fit neatly into the old data, in most cases, it will not. In order to match the two data sets it is necessary to adjust either the old, the new or both sets of information. Figure 5.2a,b shows an example of this type of upgrade.

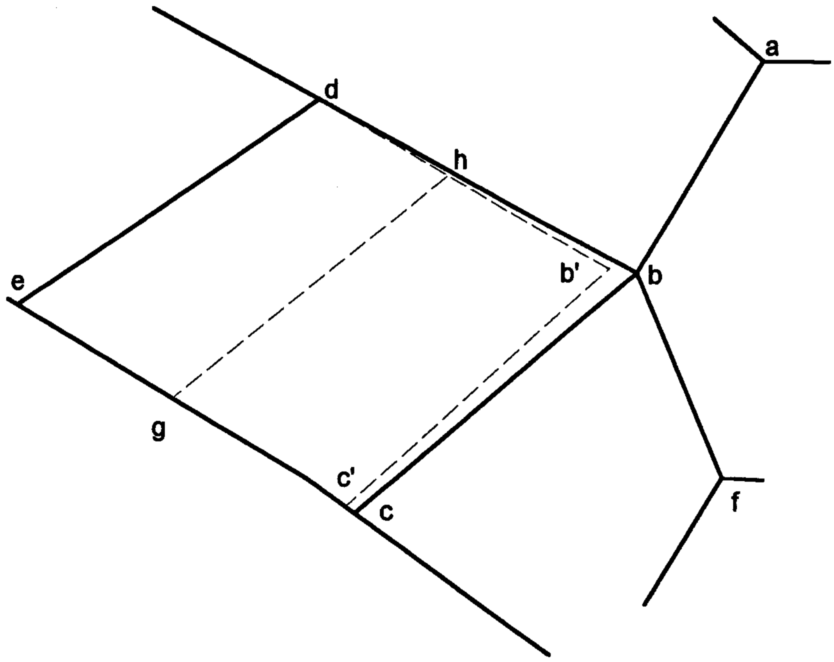


Figure 5.2a. Upgrades (Before the Update). The original area feature **bced** has, in reality, been split into two polygons. This will require the original data (full line) to be updated with new information (dashed line).

It has been suggested by some that it is more appropriate to adjust old information than to adjust new data. This is because it is thought that such an approach will, over time, improve the overall accuracy of the database (Wan and Williamson, 1995). Hence, a number of data organisations have adopted this approach for the maintenance of their spatial databases (Crook 1991, LIC 1994(c)).

As a result of this adjustment process, the positions of spatial features will be moved within the spatial database despite the fact that these features have not be moved in reality. That is, the positions of these features will be upgraded. In such cases, the upgrading process is completely uncontrolled. Furthermore, despite the implications of the term 'upgrading', this form of upgrade may actually result in a downgrading of the positional accuracy of the feature.

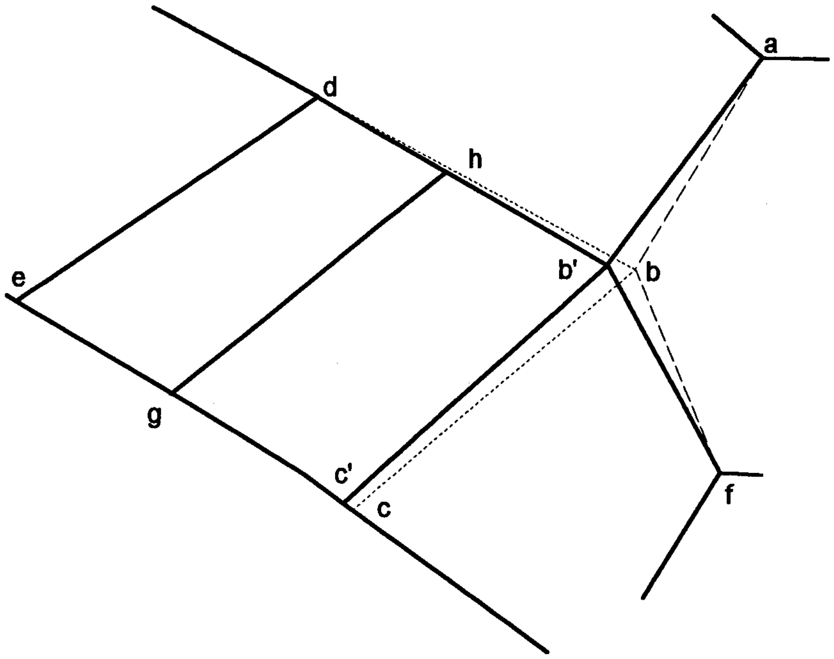


Figure 5.2b. Upgrades (After the Update). In order to include the new information, it has been necessary to adjust the original lines **a-b** and **f-b** (dashed) to the lines **a-b'** and **f-b'** respectively (full). Further, the lines **c-b** and **d-b** (dotted), which in reality have not changed, have, as a result of the updating process, been replaced by the lines **b'-c'** and **b'-d** (full) respectively. In reality all 4 of these lines remain unchanged and hence 4 upgrades have occurred.

The second source of upgrades as the result of an update occurs when part of the update information being added to the database actually contains original features which have not changed in reality. In such cases it is possible that the positional information for these features will be different from that used prior to the update. This will occur, for example, in situations where a particular update consists of a large change over a large area, such as a multi-lot subdivision of cadastral parcels. Certain features within this update may actually correspond to original (pre-updated) features, yet, due to the way the data was captured will have different positions. The user has little choice but to include this new information and hence, once again, the feature is upgraded. Figure 5.2a,b also gives an example of this source of upgrade.

In some cases it may be considered necessary to perform a positional adjustment of an entire spatial database. This might be done in an attempt to improve the spatial accuracy of the database and is of particular interest to those GIS users wishing to merge a number of data sets (Baker, 1991). It is beyond the scope of this thesis to discuss the many reasons for and against performing such an operation. For discussion on the issues involved see Masters (1988), Totten (1989), Hintz and Onsrud (1990), and LIC (1994(c)). However, it is obvious that, as a result of performing such an operation, large amounts of spatial information will be upgraded. Thus, it is important to look at the processes involved in large scale upgrading of a spatial database.

A number of techniques for performing large scale upgrades have been developed. These range from least squares adjustments using graphical features as observations, to techniques based on the independent model block adjustment used in photogrammetry. Some methods even allow for certain geometric constraints (polygon area, straight lines, angle sizes) to be included in the adjustment (Hesse *et al.* 1990, Hintz and Onsrud 1990, Clatworthy 1994(b, c), Tamin and Schaffrin 1995).

In general, upgrading techniques have been developed for the express purpose of upgrading cadastral data sets. As such, a number have incorporated techniques to take advantage of features peculiar to cadastral information. The MAGIC technique proposed by Hesse *et al* (1990), for example, uses certain known characteristics about cadastral boundaries as *pseudo observations* within a least squares adjustment. Its features include such things as the ability to identify angles between vectors which are within a range around certain known angles (90° and 180°) and, as part of the least squares adjustment, force these angles to remain constant. Another technique, proposed by Tamin and Schaffrin (1995), applies certain geometric constraints to features within the data set as part of a least squares adjustment. These constraints include such things as maintaining road widths, right angles and tangency between lines and curves.

The method proposed by Clatworthy (1992(a, b), 1994(b, c)), uses the principles of the independent model block adjustment used in photogrammetry, to adjust cadastral information. The basis of this approach, whilst not entirely clear from the proponent's documentation, is to treat an area of the data set (eg. a city block) as an independent model whose coordinate origin, scale and orientation of axes can be independent of other models (Clatworthy, 1994(c)). This model can then be adjusted via a least squares adjustment to fit known control survey points in much the same way control is used to adjust aerial photography. This method is presently being tested by the LIC as a possible method for the upgrading of the DCDB (Baker and Paxton 1994, LIC 1994(c)).

As mentioned previously, it is not within the scope of this thesis to discuss the reasons why a user may wish to use one of these methods to upgrade a particular data set. Nor is it necessary to discuss which of those methods proposed for adjusting data sets is the most appropriate for the local government situation. It is however important to understand that such methods exist and the end result of using any of these methods, as far as the management of positional relationships is concerned, is that each method will result in large amounts of data being upgraded.

5.2.2.2 Upgrading and Positional Changes

As previously mentioned, an upgrade implies that new information about the position of a feature has been obtained or, in some cases, calculated, despite the fact that the feature has not moved in reality. Thus, as the upgraded feature has not moved, any positional relationships (both defined and measured) that existed between it and other features are still relevant. Therefore, in order to ensure the positional integrity of these related features, they should also be upgraded such that the affected positional relationship is maintained. This result is different from that for updates and demonstrates the effects different types of positional change have upon positional relationships.

Neither the form nor class of a positional relationship will have any effect upon how that relationship is affected by an upgrade to a master feature. In the case of a slave feature being upgraded, however, the result is different. In this case the relationship class plays an important role in how that relationship is affected.

For measured relationships, an upgraded position for a slave feature implies that new information about its original position has been determined. Thus, given that the positional relationship was only used to determine this same position, the new information overrides the relationship which becomes invalid. It can therefore be seen that it is most important for users of spatial information to understand the processes involved in upgrading a spatial database. Otherwise incorrect use of the various upgrading techniques could quickly degrade the accuracy of a database by destroying all original positional information.

Whilst the effect upon a measured positional relationship of an upgrade to a slave feature causes some concern, the effect upon a defined relationship actually causes a conflict of information. In this case, given that the position of the slave feature was originally defined via a positional relationship, theoretically it should not be possible to determine new information about the original position of that feature. Therefore, an upgrade to the position of the slave feature does not imply that the definition was incorrect, rather it implies that the original position of the master feature was incorrect. However, to enforce the relationship and reposition the master feature would imply that its position was dependent upon the position of the slave feature. Whilst, in reality, this could be possible, for consistency it should not be allowed, as it contradicts the definition of a positional relationship. This problem can be best illustrated by example.

If an electoral boundary is defined as being coincident with the centreline of a road corridor, then a defined relationship exists between the two features. Thus should the centreline of the road (the master feature) be upgraded or updated for any reason, the electoral boundary (the slave feature) should undergo a similar change so as to ensure the spatial integrity of the database. Furthermore, an update to the electoral boundary would imply that the definition of the position of that feature had changed and hence the original relationship had become invalid. However, an upgrade to the position of the electoral boundary implies that new information about the original position of this feature had been acquired. The fact that this position had been defined however, implies that this position is completely dependent upon the position of road centreline. New information about the original position of the electoral boundary therefore implies that the road centreline has undergone an upgrade. That is, it is not possible to upgrade the position of the electoral boundary without a similar change having occurred to the road centreline. In such cases the user must decide which action to take with respect to the features involved.

It can therefore be seen that, as with updates, the reaction of a positional relationship to an upgrade is dependent upon the place the upgraded feature holds within the relationship. In the case of an upgrade to a slave feature the class of the relationship is also important. The effects of an upgrade on different positional relationships are summarised in Table 5.3.

Feature Type	Relationship Class	Affect on Positional Relationship
Master	Measured	Relationship remains valid.
	Defined	Relationship remains valid.
Slave	Measured	Relationship becomes invalid.
	Defined	Conflict of Positional Information. User must decide.

Table 5.3. Effect of an Upgrade on a Positional Relationship. The effect of the upgrade is dependent upon the position of the upgraded feature within the positional relationship and, in some cases, the relationship class.

5.2.3 Combinations of Updates and Upgrades

It has been shown that, whilst in a number of cases it is important to reposition a feature after a positional change, in other cases the relationship between the features will become invalid. Such is the case for an update to a master feature. However this invalidation of the relationship will be a cause of concern for some users of positional relationships. The problem occurs if the user decides, at a later time, to perform an upgrade of the area including the updated feature. It will not be possible to reposition any slave features using a stored relationship as the relationship ceased to exist after the update.

It has been seen that some spatial databases are dynamic in nature. This means that positional relationships involving features within these dynamic databases will have short life spans. That is, due to the frequency with which some spatial features are updated and the effect of some of these changes upon certain positional relationships, many of these relationships will become invalid within a short period of time. Thus, the problem outlined above will make it difficult to safely upgrade such data sets without compromising the positional accuracy of data sets containing slave features.

This problem provides a good argument for the storage of historical information with spatial databases. If such information is kept, it would be possible to include it within the upgrade process. Once the upgrade process (including this historical information) has been completed, the maintenance of positional relationships could take place. This would ensure the spatial integrity of features related to this historical information.

5.2.4 Summary

The findings in this section show that whilst the maintenance of a positional relationship after a positional change has occurred may certainly be required in some situations it will not be required in all situations. Therefore techniques which simply maintain a relationship cannot possibly manage all positional relationships in a GIS. Rather it is necessary to develop a method which is able to determine the type of positional change that has occurred, the nature of the affected positional relationship and the place the affected feature holds in that relationship. Using this information a set of rules, based upon the findings in this section, can be used to determine the required action to take with respect to other features in the affected relationship.

Chapter 6 looks at a number of the issues involved in the development of a comprehensive positional relationship management system for local government using the findings of Chapters 3, 4 and 5. However, before this it done it is first necessary to investigate one final aspect of positional changes in a local government GIS. That is, how these changes are integrated into a spatial database.

5.3 Integrating Positional Changes into a Spatial Database

In the previous sections it was shown that positional changes play an important role in the life of a spatial database. If the process of updating a particular data set is not performed, that data set may soon become out of date and hence less useful than it might otherwise be. Furthermore, it has been revealed that a number of the data sets used by local government, and especially the most used data set (the cadastre), are dynamic data sets for which continual updating is essential. It has also been mentioned that a number of spatial data users have identified a need for wholesale upgrading of entire data sets to gain an improvement in spatial accuracy. In general all of these tasks will be performed by the custodian of the particular data set.

One important subject which has not yet been discussed is the fact that, whilst many councils use certain data sets in their GIS, they are not responsible for the maintenance of these data sets. For example, a number of councils in New South Wales use the LIC's DCDB. This fact does not play any role in the nature of positional relationships, however, it is does affect the implementation of any method for managing these relationships. The following section, therefore discusses the issues involved with propagating updates from a data supplier to a data user.

5.3.1 Propagating Updates

In a number of circumstances, users of spatial information are not responsible for the maintenance of some of the data sets they use. Rather, they rely upon outside sources to maintain particular data and supply updates of that data at varying intervals. This is generally the case in situations where the data relates specifically to the functions of, or has been purchased from, some other authority. For example, a particular council might acquire its cadastral data set from an organisation which is responsible for the capture and maintenance of a DCDB (eg. the LIC in NSW). That same council may also buy soil type information from some other source (eg. the Soil Conservation Service in NSW) and information about contaminated sites from yet another source (eg. the Environment Protection Agency in NSW).

It is beyond the scope of this thesis to discuss the many reasons why it is beneficial for councils to rely upon other organisations to maintain the data sets they use. These issues have been investigated thoroughly by Mullin (1988). Of interest to this project, however, is the fact that, as a result of this practice, it is necessary for data suppliers to be able to propagate these updates to councils. Once again, the methods used to perform this task are not strictly within the scope of this thesis, however it is, perhaps, of benefit to look briefly at the processes used.

There has been some debate on how to supply updates of information for large spatial databases. Mullin (1988) identified 4 different methods for providing updates to outside users. They are:

- Bulk File Updates - an entire map sheet, or similar unit, is supplied to the user. This map sheet is used to replace the user's existing map sheet.

- Block Data Updates - similar to Bulk File Updates except that each map sheet is divided into smaller blocks or tiles. Individual blocks are then replaced.

- Incremental Updates - Only that information which has been changed is supplied. The user is provided with both the new data as well as an indication of what data has been superseded.

- Alert Updates - Rather than providing information about what changes have occurred, only information about where changes have occurred is provided. Information about the change can then be received as a bulk file or block.

Traditionally, updates have been propagated using the bulk update method or 'whole file replacement' (Hesse and Jacoby, 1995). This is due mainly to the fact that it is a relatively simple approach unlike, for example the incremental approach. There has however been a move towards use of incremental updates (Dominguez *et al*, 1994) as they allow for a vast reduction in the time and cost of integrating updates (Hesse and Jacoby, 1995).

The reason that propagated updates are of interest to this project, is that an essential function of a system for managing a positional relationship is the ability to detect those features which have undergone a positional change. Furthermore, it is necessary that the system be able to detect what type of positional change has occurred. That is, whether the feature has been updated or upgraded. One feature of each of the propagation methods developed is that the only data supplied are spatial data. Thus whilst information about what has changed may be supplied, there is no information about why this change has occurred. As a result, if the positional relationships to be managed include features in data sets which are propagated to the user from another authority, the detection process must be able to be performed using only the spatial data supplied. That is, the detection process must be independent of the updating and upgrading processes.

The problems associated with detecting positional changes will be discussed in more detail in Chapter 6.

5.4 Conclusion

The aim of this chapter was to investigate the types of positional change that take place within spatial data sets and the effect of these changes upon positional relationships. It has been shown that two types of positional change take place within spatial databases and that the frequency with which they take place is dependent upon the data set. It has also been shown that the effect of these changes upon a positional relationship is dependent upon the type of positional change that has occurred, the class of the positional relationship and the place (master or slave) the affected feature holds within the relationship.

This chapter has also shown that any method developed to manage positional relationships must be able to recognise different types of positional change and take the action appropriate for the particular situation. In Chapter 2 a number of methods proposed for managing positional relationship were reviewed. It is important to note that none of these methods differentiated between updates and upgrades.

In fact a number of the issues involved in the management of positional relationships identified in this thesis were not addressed by any of these techniques. The following chapter will therefore detail the requirements of a method for managing positional relationships in the local government context and discuss some of the issues involved in developing such a system.

6. Managing Positional Relationships in a Local Government GIS

6.1 Introduction

The investigations in Chapters 3, 4 and 5 have revealed a number of important facts about the nature and use of positional relationships in local government GIS. In Chapter 3, the study of the spatial data sets used by councils in New South Wales found that the number and diversity of the data used by an individual council is, potentially, large. Chapter 4 identified a number of different positional relationship types which are used in the creation of these data sets. It also showed that there are distinct classes of positional relationships, dependent upon the purpose for which the relationship exists. Finally, in Chapter 5 it was found that two types of positional change take place within local government GIS and that both of these changes have different effects upon positional relationships. However, it was shown that these effects are also dependent upon the relationship class (Section 4.4.1) and the place the updated or upgraded feature holds within the relationship (ie. Master or Slave feature) (Section 4.4.2).

The findings of these investigations raise a number of important issues with regard to the management of positional relationships in local government. The purpose of this chapter is to discuss these issues with respect to the development of such a system. These discussions will include:

- the local government requirements of a management system;
- the choice of a management technique;
- the detection of positional changes;
- a 'rules base' for determining what action should be taken after a positional change has occurred;
- techniques for maintaining specific relationship types;
- the development of models for positional relationships; and
- the integration of a management system into a local government GIS.

6.2 Requirements of a System for Managing Positional Relationships in a Local Government GIS

Before any development process begins, it is first necessary to develop a set of criteria which the final product must fulfil. Without such guidelines it is not possible for the system developer to know what is required of the final product. This section, therefore, will develop a set of criteria for a system to manage positional relationships within a local government GIS. These criteria will be based upon the knowledge gained from the investigations described in Chapters 3, 4 and 5.

6.2.1 Independence from Data Set

In Chapter 3 a large number of spatial data sets were identified as being used by local government. It was also revealed that the nature of the data represented in each of these data sets is diverse. It can therefore be seen, that any method for managing positional relationships in all local government data sets must be independent of the data set. That is, it is necessary to ensure that any method developed is not specific to a particular data set. Rather, the method must be able to manage positional relationships between features in any data set, regardless of the nature of the data.

6.2.2 Independence from Positional Relationship Type

The investigation into the types of positional relationships used in local government revealed that a large number of different relationships are used. Furthermore, these relationships varied from simple, measurement based, relations to complex mathematical models. It was also found that, whilst some forms of relationship are commonly used, others may only be used by particular organisations. Finally, it is was found that it is not necessarily the case that the same relationships will be used by different organisations to construct the same data set.

The number and variety of different positional relationships in use and the fact that different relationships can be used to create the same data set, suggest that any method for managing positional relationships cannot be relationship type specific. That is, the method must be independent of the form of the positional relationship used.

In fact the complexity and diversity of different relationships is such that it is necessary that any method be flexible, so as to allow the user to define and manage any positional relationship type.

6.2.3 Independence from the Updating and Upgrading Processes

In Section 5.3 it was shown that there are basically two methods by which local governments can integrate positional changes into their data sets. They are:

- In-House updates - the data set is updated or upgraded within council using standard editing (eg. COGO, digitising and transformations) or upgrading techniques.
- Propagated updates - the user receives information about updates or upgrades to a data set from an outside source. These updates and upgrades come in one or more of the following forms: block, tile, incremental, alert + block/tile (Mullin, 1988).

In many cases, councils will use both of these techniques.

It would be relatively simple to incorporate the management of positional relationships into in-house updates. As a particular feature is updated or upgraded, a decision, using stored positional relationship information, could be made as to whether that relationship should be maintained. The appropriate action could then be taken.

However, in the case of propagated updates, the updating or upgrading processes have occurred beyond the control of the user. The organisation responsible for supplying the updated information will have no knowledge of the positional relationships employed within a particular data user's GIS, nor will it have access to that user's other data sets. Therefore it is not possible for this organisation to manage positional relationships. In this case, the user would require some other method for managing positional relationships if an integrated method is developed for in-house updates.

Rather than using different methods for managing positional relationships for the different updating techniques, it seems more efficient to separate the processes of integrating positional changes and management of positional relationships. This would allow the management process to be performed for all data sets using a common technique. That is, any method developed should be independent of the updating and upgrading processes.

6.2.4 Correct Management of Positional Relationships

The most important part of managing positional relationships is to ensure that they are managed correctly. This means determining the correct action to take after a positional change has occurred and taking that action. In Chapter 5 it was shown that this action will be dependent upon:

a. the type of positional change.

   There are two types of change that can occur.

   - Updates - the feature has undergone some physical change such that its position in the real world has been changed, or has been redefined.

   - Upgrades - the position of the feature in the real world has not changed or been redefined. Rather, new information about the feature's original position has been used to reposition it in the GIS data set.

b. the class of the positional relationship.

   In Chapter 4 it was shown that there are two different classes of positional relationship used in a local government GIS. They are:

   - Measured relationships - the position of one feature at one particular time has been determined using measurements to other features.

   - Defined relationships - the position of one feature, in the real world, is defined at all times by its relationship to other features.

c. the place the updated or upgraded feature holds within the relationship.

A feature can either be a:

- Master Feature - the position of some other feature is dependent upon the position of this feature.
- Slave Feature - the position of this feature is dependent upon the position of one or more Master features.

In order to correctly manage a positional relationship, any method developed must be able to recognise each of these characteristics, determine the appropriate action and ensure that this action is performed.

6.2.5 Correct Maintenance of Positional Relationships

Whilst it is important that any method to manage positional relationships be independent of the relationship type (Section 6.2.2), it is also necessary that the method be able to maintain a relationship correctly. That is, it must be able to determine the correct position of a Slave feature with respect to its Master feature(s) based upon the form of the positional relationship between these features.

6.2.6 Maintenance of Internal Positional Relationships

A subject which has not been discussed so far, is the fact that positional relationships will often exist between features in the same data set. For example, in data sets where one straight line in reality, is represented by a number of straight lines in the GIS, it is important to ensure that the one straight line actually remains straight. This might happen in cadastral data sets where the street frontage of a city block is represented by a number of lines representing the frontage of each cadastral parcel.

The existence of these internal positional relationships has been recognised by a number of authors when developing techniques for upgrading data sets (Hesse *et al*, 1990 and Tamin and Schaffrin, 1995). These techniques include, as part of their adjustment processes, the ability to enforce certain internal relationships such as 90° and 180° angles between line features.

A requirement of a method for managing external positional relationships would therefore be that the method be able to perform its functions without compromising these internal relationships. In fact it may be appropriate that the management system be able to manage these relationships in order to maintain the internal spatial integrity of each data set.

6.2.7 Automatic Positional Relationship Management

The reason for developing a method to manage positional relationships in a local government GIS is that, whilst it is a fairly repetitive task, it is also a complicated task. As a result, if it is performed incorrectly, it can lead to large errors in a data set. In order to avoid the introduction of these errors, it is necessary to limit the amount of work required of the user. That is, there should be as little user interaction within the process of managing positional relationships as possible.

6.3 Techniques for Managing Positional Relationships

In Chapter 2, three techniques for the maintaining positional relationships were reviewed. These techniques were:

- the Transformation Method;
- the Database Method; and
- Object Orientation.

It was found that each of the above methods had certain advantages and disadvantages with respect to their implementation and their ability to maintain particular types of relationships. This review however, did not investigate whether these methods are appropriate for managing positional relationships in a local government GIS. As the findings of this thesis suggest that maintenance of a relationship forms only one part of the management process, it is necessary to examine the ability of each method to fulfil the set of requirements developed in Section 6.2.

6.3.1 The Transformation Method (see Section 2.2.1)

It was noted in Section 2.2.1 that the principle of the transformation method is to apply the same transformation to Slave features as has occurred to their related Master features. This is done by introducing control points, derived from the original base data, into the data set containing Slave features. This data set is then transformed such that the introduced control points become coincident with their positions in the upgraded base.

Section 2.2.1 further noted that such a process cannot maintain specific relationships. Rather, it attempts through the transformation, to maintain features in all data sets, in the same relative positions. This method, therefore, does not comply with Criteria 6.2.5.

It was also revealed that a number of tools have been developed which integrate the upgrading and transformation processes. These tools may even use information from data sets other than the base as control for the adjustment. Unfortunately, however, as they require the upgrading and positional relationship management processes to be performed concurrently, they are not independent processes and therefore do not satisfy Criteria 6.2.3.

It should be remembered that the transformation method was developed to maintain positional relationships after the wholesale upgrading of a cadastral data set. That is, it was not designed to deal with updates or upgrades caused as a result of an update. In fact, as this method assumes that a transformation has occurred to the base data, it cannot maintain relationships where no transformation has occurred. An update does not constitute a transformation.

Thus, the transformation method, whilst allowing the user to maintain relative positions after the wholesale upgrade of a data set, cannot actually be used to manage positional relationships in all situations. Therefore, any attempt to develop a management system should not look to this method alone.

6.3.2 The Database Method (see Section 2.2.2)

The database method was discussed in Section 2.2.2 and uses one or more database tables, containing positional relationship information, to aid in the management of positional relationships. As information about specific relationships is stored, this method can truly maintain a positional relationship (Criteria 6.2.5).

In fact, unlike the transformation approach, the database method can actually fulfil all criteria given in Section 6.2.

- It is independent of the type of data (Criteria 6.2.1).
- With careful design, it can be independent of the type of relationship (Criteria 6.2.2) and can be used to manage a great number of possible positional relationships (Criteria 6.2.5).
- It is not limited to being performed at the same time as an update or upgrade. Those using this method do not therefore need to be the custodian of a particular data set. Positional relationships to features in related data sets can be managed at some later time or, other users of the base data can manage their related information without knowledge of parameters used for upgrading. It thus satisfies Criteria 6.2.3.
- It can be designed so as to monitor or even manage internal positional relationships (Criteria 6.2.6).
- Unlike the transformation method, it is flexible and is thus not limited to being solely a process for maintaining positional relationships after an upgrade. Other functions, or 'rules', can be built into the method to allow for some degree of 'intelligence' for the system. That is, these rules base can be used to manage positional relationships correctly (Criteria 6.2.4).
- Finally, it requires little user intervention (Criteria 6.2.7).

Despite the fact that the database method can fulfil all the requirements for managing positional relationships, Section 2.2.2 noted that there are number of drawbacks with this technique. These difficulties mainly occur due to the complexity of the required system, and must be addressed in order to implement a successful system. A number of these issues will be discussed in later sections of this chapter, however it is important to note that this method can be used as the basis of a management system.

6.3.3 Object Orientation (see Section 2.2.3)

It was recognised in Section 2.2.3 that an object-oriented GIS is well suited to performing the task of maintaining positional relationships. With knowledge of the nature of positional relationships and the mechanisms of positional change, a carefully designed object-oriented system can also fulfil all requirements in Section 6.2. That is, an object-oriented system can be used to manage positional relationships. There is however, in the area of local government, one small problem. The problem is that many councils have already invested large amounts of time, effort and money in developing their GIS. Further, this has generally been done using a conventional, layer based, GIS package. Unfortunately these packages are not conducive to the introduction of the concepts of object-orientation. Thus, whilst this technique should be considered for the management of positional relationships with the introduction of new technology, it would seem that use of this method will be difficult to implement on existing systems.

6.3.4 Summary of Maintenance Techniques

As the ability to manage positional relationships for different types of positional change, and the ability to maintain many different types of relationship, are critical for local government, the transformation method is not appropriate for the local government case. It is thus, necessary to turn to either the database or object oriented approaches as both these methods can be implemented in such a way as to fulfil each of the requirements set out in Section 6.2.

The remainder of this chapter, therefore, will concentrate upon the development of systems which use the object-oriented or database approaches.

6.4 The Data Required to Manage Positional Relationships

The findings in Chapter 5 and the set of criteria developed in Section 6.2 show that the management of positional relationships in a local government GIS is not simply an exercise in maintaining relationships. Rather it is necessary to be able to determine what has changed, why it has changed and what should be done before actually taking any action.

A system to manage positional relationships will therefore involve a number of processes. They are:

1. Detect a positional change to a feature and determine the type of change that has occurred (update or upgrade);

2. For each positional relationship affected by this change determine the appropriate action; and

3. Perform that action.

Each of these processes involve the collection or use of certain pieces of information. The following sections discuss the data required to successfully manage a positional relationship with respect to both the database and object-oriented methods.

6.4.1 Detecting a Positional Change

As far as the management of positional relationships is concerned, the most important function with respect to the occurrence of a positional change, is to detect this change and determine its form. In object-oriented systems, the detection of a change is not a difficult process. In layer based systems this detection process is a little more difficult. However, in both cases, determination of the type of change that has occurred is a difficult task.

In Chapter 5 two types of positional change were identified as occurring in local government spatial data sets. These changes are updates and upgrades. However, the occurrence of these changes will result in one of three changes taking place within a spatial database. These changes are:

- Features (points, lines or polygons) may be deleted from the database;

- Features may be added to the database; and
- Features may be moved within the database.

In general an upgrade will only result in a feature being moved within a database. An update, however, may result in any of these three changes taking place. That is, a feature ceasing to exist will result in a deletion, a new feature will result in an addition, and a feature being moved in reality will result in that feature being moved within the database.

Whilst detecting a change may be a relatively simple exercise, given the fact that both an upgrade and an update can result in a feature moving within a database, determination of the type of change presents a more complicated problem. This problem is further complicated by the fact that Criteria 6.2.3 requires the updating and upgrading processes to be independent of the management system. Thus, any solution to the problem of determining the type of change should not be integrated into these processes.

The techniques used to detect changes and determine the form of these changes will be dependent upon the management technique used.

6.4.1.1 Detecting Changes in an Object-oriented System

The detection of a positional change to a feature in an object-oriented system is a relatively simple task. In fact it is possible, in these systems, to define an object such that the act of changing its position, will cause certain processes to be performed. An example of such a process might be to activate positional relationship management for that object.

However, as mentioned previously, the process of determining the type of change that has occurred is somewhat more difficult. A partial solution, however, may be to develop and use a convention for the unique identification of objects.

The fact that it is necessary to use an object-oriented or database solution to manage positional relationships implies that every feature in every data set used must be uniquely identified. If this were not the case it would be impossible to relate individual features via the database, or address individual objects within the object-oriented system. As each identifier is unique, it is possible to develop a crude solution for detecting the form of a positional change based upon the assignment of these identifiers.

One such convention is to ensure that in all cases of an update, the identifier of the updated feature is changed. Thus, a feature whose identifier remains the same after it has been moved, must have undergone an upgrade.

There is, of course, one form of positional change which cannot be detected using this convention. This change occurs when an update results from a feature being moved in reality. In this case it will not be possible to maintain a defined relationship with this updated feature as it will be impossible to detect the form of the update. This problem is best illustrated by an example.

In Figure 6.1a the Building line has a defined positional relationship with the cadastral boundary identified as Line 1. The relationship is in the form of a offset of 5.0 m. That is, the line feature 'Building Line' is offset to the line feature 'Line 1'.

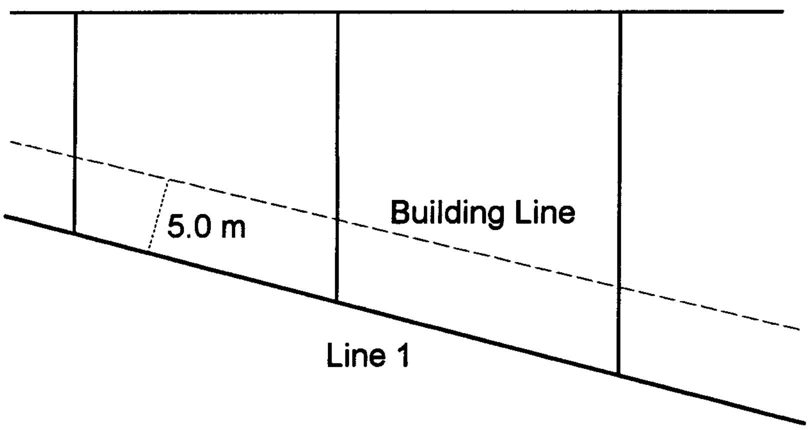


Figure 6.1a. Detecting Positional Changes (Before the Update or Upgrade). The Building Line is defined as being offset 5.0m from the line Line 1.

If the cadastral boundary were to undergo an upgrade as in Figure 6.1b, the above naming convention would require that the identifier of this boundary 'Line 1' remain unchanged. This would indicate to the change detection process that an upgrade to the position of this feature had occurred. The relationship between Line 1 and the Building Line would be maintained.

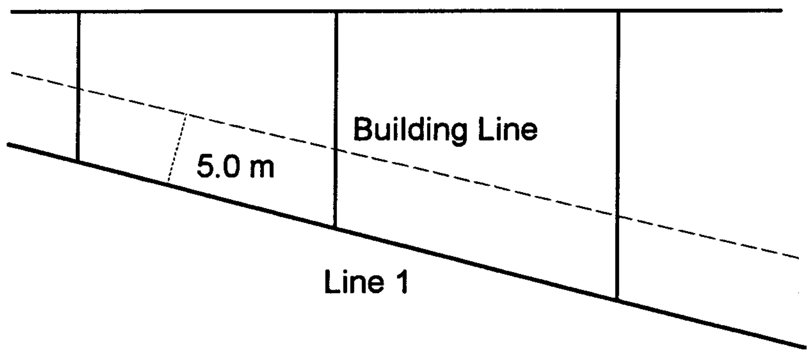


Figure 6.1b. Detecting Positional Changes (After an Upgrade). The line feature identified as Line 1 has been upgraded and hence is still called Line 1. The upgrade is detected and the Building Line repositioned with respect to Line 1.

If however if the cadastral boundary were to undergo an update such that it was moved towards the Building Line (Figure 6.1c), the naming convention would require Line 1 to be renamed, say to Line 2. This is done in order to indicate that an update had occurred. However, the positional relationship originally existed between the Building Line and Line 1 (not Line 2). Therefore, whilst the positional change will be detected, the fact that the cadastral boundary had been moved will not be detected. Rather, it will be assumed that the feature 'Line 1' no longer exists and a new feature 'Line 2' has been created. As 'Line 1' no longer exists any relationships that feature may have been involved in will become invalid and hence the defined position of the Building Line, as represented in the GIS will be incorrect.

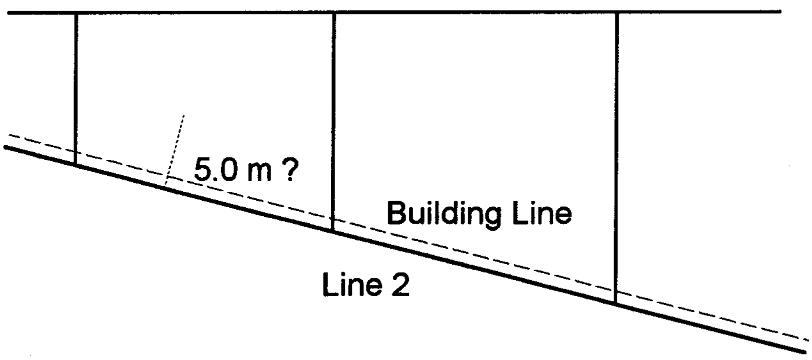


Figure 6.1c. Detecting Positional Changes (After an Update). The line feature identified as Line 1 has been updated and hence is renamed Line 2. This positional change is not detected and hence the Building Line is repositioned with respect to Line 2.

The problem of detecting the type of positional relationship that has occurred is a perplexing yet extremely important problem. Further discussion of this problem will be given in this chapter and Chapter 7.

6.4.1.2 Detecting Changes in a Layer Based GIS

There are a number of ways in which to detect a positional change to features in a layer based GIS. However, as with the object-oriented system, it is necessary to choose a method which is able to detect all changes, differentiate between the different types of change, and perform these functions for both 'in house' and propagated updates.

One possible method is to ask the user to create a list of the required information before, during or after the updating and upgrading processes. This list would contain information identifying every feature which has undergone a positional change, along with the type of change that has occurred. Unfortunately, this method has a number of disadvantages. Firstly, it is not possible to ensure that all changes will be detected, nor is it possible to ensure that those changes that are detected, are correctly identified as updates or upgrades. Secondly, this method requires a great deal of user interaction. Finally, in the case of propagated updates and upgrades, the user would find it difficult to create a complete list of all changes. It is not actually infeasible that, in these cases, the updating authority supply the required information, as many GIS systems allow the storage of such feature level metadata. However it is possibly unwise for users to expect this to happen. Hence, this method is not suitable.

A second method is to automatically collect update and upgrade information as the changes are made. This method, however, encounters similar difficulties in situations where the user is not actually responsible for the maintenance of a particular data set.

A simpler, and more efficient, method for detecting positional changes is simply to compare the newly updated or upgraded data set with a copy taken before any changes were made. This comparison would allow for automatic detection of all new features, deleted features and using the identification convention outlined above, all upgraded features, although it suffers the same inability to detect updates where a feature is moved.

Importantly, this method can be applied in situations where the user is both responsible for data set maintenance, as well as where they are not. That is, the comparison is not a part of the actual maintenance process. This process therefore satisfies Criteria 6.2.3.

6.4.1.3 Summary

Assuming all features within a data set are uniquely identified, the detection of positional changes in that data set is not a difficult task. The very nature of objects can be used to detect changes in an object-oriented system, whilst a simple comparison of old and new data sets can be used for the database method.

However, determining the type of change that has occurred is a subject which will require further thought before positional changes can be managed properly. Whilst the solution suggested in this section can solve the problem for most cases, it cannot be used to detect updates where a feature has been moved in reality. The ability to detect this type of change is essential if relationships for features affected by such a change are to be managed.

Unfortunately the solution to this problem will not be simple, as it will require a change in philosophy for a number of spatial databases. In particular, these databases will be required to store, along with the spatial information, information about the history of each feature within the database. This may be in the form of a version number, or date stamp, such that features which are updated are given a new version number whereas upgraded features are not. In both cases the identifier of the feature will remain constant if the feature still exists.

The technology to store feature level metadata of this type is readily available in a number of GIS packages However, in order to be successful the allocation and manipulation of this information must be performed as part of the updating and upgrading processes. Thus problems associated with the use of outside data sets and 'version management' of data sets must first be addressed.

The ability to determine the type of positional change that has occurred is extremely important to the process of managing positional relationships. One of the most important findings of this thesis is that different types of positional change affect different relationships in different ways. A solution to this problem must therefore be found.

6.4.2 Determining the Required Action

Once a positional change has been detected and its form determined, it is necessary to determine the correct action to be taken with respect to every positional relationship involving the changed feature. That is, for each positional relationship involving an updated, or upgraded feature, it is necessary to determine whether or not that relationship remains valid as a result of the change. This knowledge can then be used to determine the required action. The action will be either to maintain the relationship by re-positioning a related feature, extinguish the relationship, or simply do nothing.

Chapter 5 discussed the factors which determine how a positional change will affect a positional relationship. It revealed that the effect will not be dependent upon the type of positional relationship. Rather, relationship class, the place the updated or upgraded feature holds within the relationship (Master or Slave), and the type of positional change that has occurred, determine how a relationship will be affected. These effects are summarised in Table 6.1.

It should be noted that Table 6.1 does not include the situation where a feature is added to the database (ie. an Update - Addition). This omission is possible for two reasons. Firstly, as the feature is new to the database, it cannot have a previous position. Therefore technically, it has not undergone a positional change. No positional relationships have been affected by the addition of this feature and hence no positional relationships need to be managed.

Secondly, it possible that the user has not yet defined any positional relationships for this feature or does not wish to. In either case, there does not exist information within the GIS about relationships involving the new feature. It is therefore not possible to manage a relationship.

Thus in the situation where a feature has been added to the database, whilst there is a need for a user to be able enter information about any new positional relationships, the management of these positional relationships is unnecessary and in some cases impossible.

Type of Change	Affected Feature	Relationship Class	Affect on Positional Relationship
Update - Moved	Master	Measured	Relationship becomes invalid.
		Defined	Relationship may remain valid
	Slave	Measured	Relationship becomes invalid.
		Defined	Relationship becomes invalid
Update - Deleted	Master	Measured	Relationship becomes invalid.
		Defined	A new Relationship should be defined.
	Slave	Measured	Relationship becomes invalid.
		Defined	Relationship becomes invalid.
Upgrade	Master	Measured	Relationship remains valid.
		Defined	Relationship remains valid.
	Slave	Measured	Relationship becomes invalid.
		Defined	Conflict of Positional Information. User must decide.

Table 6.1. The Effect of Positional Changes on Positional Relationships.

Table 6.1 shows that, in most cases, positional relationships affected by an update should be extinguished as they have become invalid. However in two particular cases this will not be the required action. These cases both occur when a Master feature, involved in a defined relationship, is updated. In these cases the action necessary will be dependent upon the form of the update. If the feature has been moved in reality, it may be necessary to maintain the relationship. If the feature has been deleted, it may be necessary to define a new relationship for the Slave feature. Once again, the ability to be able to detect the type of a positional change that has occurred (Section 6.4.1) is essential in these cases.

Unlike updates, Table 6.1 shows that the action required after an upgrade varies markedly between different relationships. In the case of a Master feature undergoing an upgrade, the required action is to maintain any relationship. However, if a Slave feature is upgraded, the required action will be to extinguish any measured relationship, or, in the case of defined relationships, the user may be required to determine the action.

So far, three possible 'actions' that can be taken when managing positional relationships have been identified. The relationship can be maintained, it can be extinguished, or a new relationship can be defined. However there is one situation where a different action may be required. This occurs when an upgrade to a Slave feature has occurred as a direct result of its relationship to its Master feature(s) having being maintained. In these cases the positional relationship remains valid and the Master and Slave features should be in their correct relative positions. Hence the necessary action is to 'do nothing'.

The above case shows that an essential part of determining the required action, is the ability to determine the current status of the features involved in the relationship. That is it is necessary to be able to determine whether these features are in their correct positions with respect to the relationship. In order to perform this function, it is necessary to be able to reconstruct specific relationships.

Table 6.2 shows the action that should be taken for each case of a positional change occurring to features in a spatial database. This table demonstrates, yet again, the importance of being able to automatically detect the type of positional change that has occurred as the ability to determine the required action is dependent upon this information.

Type of Change	Affected Feature	Relation. Class	Relation. Status	Affect on Relationship
Update - Moved	Master	Measured	*Not Applicable*	Extinguish Relationship.
		Defined	*n/a*	Maintain Relationship.
	Slave	Measured	*n/a*	Extinguish Relationship.
		Defined	*n/a*	Extinguish Relationship.
Update - Deleted	Master	Measured	*n/a*	Extinguish Relationship.
		Defined	*n/a*	Extinguish Relationship and Define New Relationship.
	Slave	Measured	*n/a*	Extinguish Relationship.
		Defined	*n/a*	Extinguish Relationship.
Upgrade	Master	Measured	*n/a*	Maintain Relationship.
		Defined	*n/a*	Maintain Relationship.
	Slave	Measured	Correct	Do Nothing
			Incorrect	Extinguish Relationship.
		Defined	Correct	Do Nothing
			Incorrect	Conflict of Positional Information.

Table 6.2. The Action Required to Manage Positional Relationships. The required action may be dependent upon the type of positional change, the place of the affected feature in the relationship, the relationship class and the current status of the relationship.

Assuming that it is possible to determine the type of change that has occurred, the information in Table 6.2 can be used as a rules base for managing any positional relationship affected by a positional change. The processes involved in making this determination will be similar for both the database and object-oriented methods.

In order for this rules base to be used however, certain information about the positional relationship to be managed must be stored. This information includes:

1. Relationship Class - the class of the relationship to be managed;
2. Master Features - the identifiers of all Master features involved in the relationship;
3. Slave Features - the identifier of the Slave feature[1] involved in the relationship; and
4. Relationship Type - the form of the relationship. This is used to determine whether the related features are in their correct relative positions as well as to maintain the relationship.

The remaining information used by the rules base is determined at the time the relationship is managed or after a positional change has occurred.

Once the required action has been determined, it is necessary to perform that action. This will be discussed in the next sections.

6.4.3 Reconstructing a Relationship

It was revealed in Chapter 4 that there are a great many different positional relationships used within local government spatial data bases. As a result of this variety and the fact that the uses to which these relationships are put is not standard between councils, Criteria 6.2.2 requires that the management

[1] It will be shown in Section 6.5 that only one Slave feature can exist for any positional relationship.

technique be independent of the type of relationship. This will then allow users to manage any positional relationship.

Unfortunately, the fact that a management system must be able to manage any positional relationship makes the reconstruction of these relationships difficult. Reconstruction of a relationship will be required for two reasons. Firstly, it was shown in Section 6.4.2 that in some cases it will be necessary to determine whether a stored relationship is reflected by the current positions of the related features, in order to determine the correct action after a positional change. Secondly, Criteria 6.2.5 requires the method to be able to maintain a relationship correctly.

A solution to this problem is to develop a system that it is able to reconstruct the 9 fundamental positional relationships identified in Chapter 4, as well as any combination of these relationships. The fundamental relationships are:

1. Distance - the Slave point lies on a line which is a circle of known radius centred on one Master point;

2. Angle to Slave - the Slave point lies on a straight line which intersects, at a known angle, another straight line between two Master points at one of these Master points;

3. Angle at Slave - the Slave point lies on a line such that, at all times, the angle between two straight lines from that point to two Master points remains constant;

4. Distance Along a Line - the position of the Slave point is defined as being a point lying on a Master line at a known distance along that line from a Master point;

5. Point Offset - the Slave point lies on a line which is parallel to, and a known perpendicular distance, from a Master line;

6. Intersection - the position of the Slave point is defined by one of the intersections of two Master lines;

7. Line Offset - the Slave line is defined as being a line parallel, to and at a known perpendicular distance, from a Master line;

8. Relative Position - the Slave feature (point or line) is in a known position relative to a Master feature (line or polygon); and

9. Models - the positions of features in the Slave data set have been calculated using a mathematical model and the information in one or more Master data sets.

In Chapter 4 it was suggested that the above relations can be used, in some cases by themselves, and in most cases in combination[2], to describe many of the positional relationships used by local government. Thus in order to develop a system to reconstruct any relationship it is necessary simply to be able define that relationship in terms of these fundamental relations. Thus two issues are raised. The reconstruction of the fundamental relationships and methods for expressing any positional relationship in terms of them.

6.4.3.1 Reconstructing a Fundamental Positional Relationship

In order to reconstruct a positional relationship correctly, it is necessary to have certain information about that relationship. This information will include an algorithm describing the nature of the relationship, as well as any data specific to individual cases of the relationship. For example, in the case of all distance relationships, there will be an algorithm describing how to determine the position of a Slave point with respect to a Master point and there will also be actual distance information for each instance of a distance relationship within the GIS.

The natures of the 9 fundamental relationships were discussed in Chapter 4 and, therefore, will not be discussed further here. However, the data necessary to reconstruct individual instances of these relationships have not been discussed. Unfortunately, this information is dependent upon the relationship type, and as such may vary greatly. For example, in a distance relationship it is necessary to know certain measurement information, whereas in the case of a relative position it is more important to know which other features are involved in the relationship.

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[2] Combinations including the Model relationship (9) can not be created.

The variability of the data required means that this information must be stored separately for each of the 9 fundamental relations. Once an appropriate method for calculating the correct position of a Slave feature has been determined, the data relevant to this calculation can be used to reconstruct it. Methods for storing this information will be discussed in Section 6.5.

The following sections describe the information necessary to reconstruct each of the 9 fundamental relations. Diagrams of each of these relations were given in Chapter 4

6.4.3.1.1 Distance

Distance - The Slave Point P_s lies on the line LP_s which is a circle of radius *d* centred on the Master Point P_m.

The only relationship specific information associated with this particular relationship is the distance *d*. In fact, the only other piece of information necessary for calculating the position of the circle upon which the Slave feature is situated, is the position of the Master feature. Thus in order to reconstruct this relationship it is necessary to store the following information.

1. Distance - the distance information used to calculate the position of the circle upon which the Slave feature lies.

2. Master Point Feature - the identifier of the Master feature upon which the above circle is centred.

6.4.3.1.2 Angle to Slave Point.

Angle to Slave Point - the Slave Point P_s lies on the straight line L_s which intersects another straight line between the Points P_{m1} and P_{m2} at the Point P_{m1}, at an angle of θ.

The information required to maintain this relationship is slightly more complicated than that for a distance relationship. Not only is it necessary to have information about the two Master points involved, it is necessary to have knowledge of the roles these features play in the relationship. In particular it is necessary to know which of these points is the one at which the angle θ has been measured. Thus the following information must be stored:

1. First Master Feature - the unique identifier of the Master point feature at which the angle has been measured.

2. Second Master Feature - the unique identifier of the reference Master point feature. In the case of a bearing, the entry in this field is simply North.

3. Angle - the angle information.

   The angle information must be consistent. That is, in order to develop a method to reconstruct this relationship, it is necessary to have some convention about the way in which the angle information is stored. One possible convention is to store the clockwise angle from the reference Master point to the Slave point.

6.4.3.1.3 Angle at Slave Point

Angle at Slave Point - the position of the Slave Point P_s lies on the line L_s such that, at all times, the angle θ between a straight line from P_s to the point P_{m1} and a straight line from P_s to the point P_{m2} remains constant.

Whilst this relationship is different from the 'Angle To Slave Point' relationship, the information required in order to reconstruct it is similar. In this case however, the First Master Feature is the unique identifier of the first reference point used when measuring the angle, and similarly the Second Master Feature is the unique identifier of the second reference point. Thus the following information is needed:

1. First Master Feature - the unique identifier of the Master point feature to which measurement of the angle was started.

2. Second Master Feature - the unique identifier of the Master point feature to which measurement of the angle was finished.

3. Angle - the angle information. As with the Angle To Slave Point relationship, this information must be consistent.

6.4.3.1.4 Distance Along a Line

Distance Along a Line - the Slave point P_s is situated on the Master line L_m a distance *d* along that line from the Master point P_m.

In order to reconstruct this relationship it is necessary to store the following information:

1. Master Point - the unique identifier of the Master point from which the distance is measured. This point must lie on the Master line.

2. Master Line - the unique identifier of the line feature along which the distance is measured.

3. Distance - the distance information. It is also necessary to know which direction from the Master point this distance is to be measured. A possibility is to use the sign of the distance. A positive distance indicates that it should be measured towards the head of the line.

It was noted in Section 4.3.3.3 that unlike the previous three relationships, this relationship can be used alone to define a unique position for the Slave point feature.

6.4.3.1.5 Point Offset

Point Offset - The Slave point P_s lies on a line L_s which is parallel to and a perpendicular distance *d* from the Master line L_m.

In order to determine the position of a point using this relationship it is necessary to reconstruct the line offset to the Master line upon which it lies. This is performed using information about the extent and shape of the Master line as well as the offset distance. Thus the following information is necessary:

1. Master Line - the unique identifier of the line feature from which the distance is measured.

2. Offset Distance - the offset distance. This distance is measured perpendicular to the Master line.

As with the 'Distance Along a Line', relationship it is necessary to define some convention for determining the direction of the offset. For consistency it seems wise to use the same approach as used previously. That is to use the implied direction of the Master line. Offsets to the left of this line, when travelling towards the head are deemed to be negative.

6.4.3.1.6 Intersections

Intersection - The Slave point P_s lies at the *ith* intersection of the Master lines L_{m1} and L_{m2}.

In order to maintain relationships where an intersection is involved, it is necessary to determine the position of the intersection of the two Master lines. However, it is possible that these two lines will intersect more than once. Thus it is also necessary to be able to identify the intersection in question. This can be done by storing an identifier for the intersection based upon its position along one of the Master lines.

Thus, the information needed to reconstruct an intersection is as follows:

1. <u>First Master Line</u> - the unique identifier of one of the intersecting Master lines.
2. <u>Second Master Line</u> - the unique identifier of the other intersecting line feature.
3. <u>Intersection Number</u> - the instance of the intersection along the First Master Line. For example, if the intersection in question is the first intersection (along the direction of the First Master Line) the Intersection Number will be 1.

6.4.3.1.7 Line Offsets

Line Offset - The Slave line L_s is defined as being a line parallel and at a perpendicular distance *d* from the Master line L_m.

This relationship is similar in nature to Point Offset relationship (Section 6.4.3.1.5) and in fact, the information necessary to reconstruct it is the same.

1. Master Line - the unique identifier of the line feature from which the distance is measured.

2. Offset Distance - the offset distance. This distance is measured perpendicular to the Master line.

As mentioned previously it is necessary to define some convention for determining the direction of the offset.

6.4.3.1.8 Relative Positions

It was noted in Section 4.3.3.7 that the relative position category of relationships are different from the majority of positional relationships. The reason for this difference is that relative position relationships do not involve specific measurements. That is, no measured or calculated relationship exists between the related features. Rather it is the relative position of the Slave feature with respect to the Master feature which is of importance.

Section 4.3.3.7 also identified 3 possible cases for a relative position relationship.

Point - Line	The position of the Slave point remains in the same relative position with respect to the Master line.
Point - Area	The position of the Slave point remains in the same relative position with respect to the Master polygon.
Line - Area	The position of the Slave line remains in the same relative position with respect to the Master polygon.

Reconstruction of this relationship is a difficult process as it requires the ability to place the Slave feature in the same position relative to the Master feature despite the fact that measurements between these features do not exist. In order to do this, it is necessary to know the positions of the features involved before the positional change occurred. It is then possible to use a transformation type approach to reposition the Slave feature.

There are two ways in which these original (pre-upgraded) positions can be determined. Firstly, historical spatial information, stored before the positional change took place can be used. Secondly, only that information required to determine the positions of certain elements of the original features can be stored.

Unfortunately it is rare for historical information to be stored. Therefore it is necessary to use the second approach. That is, information will be stored so as to be able to reconstruct the Master feature prior to it being affected by a positional change.

The information necessary to perform this reconstruction is the positions of a number of point features which represent the Master feature. These positions themselves can be stored or positional relationships between the Slave feature and the point features can be used to determine these positions. In both cases it is necessary to store the identifiers of the points so that they can be identified in the data set after the positional change.

Reconstruction of a 'relative position' positional relationship is a difficult process when using the data base or object-oriented approaches.

6.4.3.1.9 Models

Models - The positions of features in the Slave data set DS_S have been calculated using a mathematical model and the information in the Master data sets DS_{m1}, DS_{m2}, etc.

It was noted in Section 4.3.3.8 that a relationship between data sets is different from a relationship between individual spatial features. This is because there do not exist identifiable positional relationships between features in the related data sets. It is therefore difficult to manage these relationships in the same way as relationships between individual features.

Relationships between data sets are important and must be treated with the same respect as other types of positional relationships. However the issues involved in their management are different from those involved in the management of relationships between individual features.

An example of these differences is the fact that, in some cases, it is not necessary to determine the form of a positional change, or store the class of the relationship, in order to determine the required action after a positional change. In all cases it is necessary to recalculate the positions of features in the Slave data set. In fact it could be argued that relationships between data sets fall into a class of their own such that in all cases of a positional change the required action is to recalculate the model.

The differences between the management of relationships between data sets and relationships between individual features are so great that it is not possible to perform this function using the same management system. Therefore, relationships between data sets will not be discussed further.

6.4.3.2 *Expressing a Positional Relationship*

Whilst being able to reconstruct the component parts of a user defined positional relationship is important, the ability to express that relationship is equally important. This expression can then be used to represent the form of the relationship and hence be used to determine how it is to be reconstructed. That is, the expression must be in a form such that it can be interpreted by the reconstruction processes in order to calculate a unique position for the Slave feature.

In Chapter 4, as well as giving a formal definition for each of the fundamental positional relationships, an equation for each relationship was given. These equations are:

<u>Distance</u> $LP_S = \text{dist}\,\{d{:}P_m\}$ (1)

where: d = the known distance.
P_m = the name of the Master point.

<u>Angle to Slave Point</u> $LP_S = \text{angle\_to}\,\{\theta{:}P_{m1},P_{m2}\}$ (2)

where: θ = the known angle.
P_{m1} = the name of the First Master point.
P_{m2} = the name of the Second Master point.

<u>Angle at Slave Point</u> $LP_S = \text{angle\_at}\,\{\theta{:}P_{m1},P_{m2}\}$ (3)

where: θ = the known angle.
P_{m1} = the name of the First Master point.
P_{m2} = the name of the Second Master point.

Distance Along a Line P_s = dist_line {d:L_m,P_m} (4)

where: d = the known distance.
L_m = the name of the Master line.
P_m = the name of the Master point.

Point Offset LP_s = offset_point {d:L_m} (5)

where: d = the known perpendicular distance.
L_m = the name of the Master line.

Line Offset L_s = offset_line {d:L_m} (6)

where: d = the known perpendicular distance.
L_m = the name of the Master line.

Intersection P_s = int {i :L_{m1},L_{m2}} (7)

where: i = the intersection number.
L_{m1} = the name of the First Master line.
L_{m2} = the name of the Second Master line.

Relative Position $P_s \Leftrightarrow$ relpos {L_m} (8a)

$P_s \Leftrightarrow$ relpos {A_m} (8b)

$L_s \Leftrightarrow$ relpos {A_m} (8c)

where: L_m = the Master line.
A_m = the Master area feature.

All but three of these equations include the information identified in Section 6.4.3.1 as being necessary to reconstruct these relationships. The exceptions are the Relative Position equations.

Section 6.4.3.1.8 noted that, in order to reconstruct a Relative Position, it is necessary to have knowledge of the original position of the Master feature(s). It was further suggested that this could be done by storing information about the positions of significant points which make up this feature. This information could be the actual coordinates of these points or it could be a set of positional relationships which can be used to calculate these positions with respect to the

Slave feature. Therefore, using this method, two possibilities for an equation for a Relative Position relationship exist:

Relative Position

$$P_s = \text{relpos}\,\{\,(P_{m1}{:}x_{m1},y_{m1}) + (P_{m2}{:}x_{m2},y_{m2}) + \ldots (P_{mn}{:}x_{mn},y_{mn})\,\} \qquad (9)$$

where: P_{mn} = the name of the nth Master point.
x_{mn} = the x coordinate of the nth Master point.
y_{mn} = the y coordinate of the nth Master point.

or

Relative Position

$$P_s = \text{relpos}\,\{\,(P_{m1}{:}\textit{Relation 1}) + (P_{m2}{:}\textit{Relation 2}) + \ldots (P_{mn}{:}\textit{Relation n})\,\} \qquad (10)$$

where: P_{mn} = the name of the nth Master point.
Relation n = the relationship used to calculate the position of Pmn with respect to the Slave point.

Equations 1-7, 9 and 10 can be used in varying combinations to describe many, if not all, the positional relationships between individual spatial features used in a local government GIS. For example a bearing and distance relationship can be expressed using Equations 1, 2 and 7 as follows:

Bearing and Distance

$$P_s = \text{int}\,\{\,\text{dist}\,\{d{:}P_{m1}\},\ \text{angle\_to}\,\{\theta{:}P_{m1},P_{m2}\}\,\} \qquad (11)$$

It is possible, by determining the mean of the positions of three intersections, to express a 3 point resection as follows:

<u>3 Point Resection</u>

$$Ps = ave\,(\,int\,\{angle\_at\,\{\theta_1{:}P_{m1},P_{m2}\},\ angle\_at\,\{\theta_2{:}P_{m2},P_{m3}\}\},$$
$$int\,\{angle\_at\,\{\theta_1{:}P_{m1},P_{m2}\},\ angle\_at\,\{\theta_{1+2}{:}P_{m1},P_{m3}\}\},$$
$$int\,\{angle\_at\,\{\theta_2{:}P_{m2},P_{m3}\},\ angle\_at\,\{\theta_{1+2}{:}P_{m1},P_{m3}\}\}\,) \quad (12)$$

Similarly a 3 point trilateration can be expressed:

<u>3 Point Trilateration</u>

$$Ps = ave\,(\,int\,\{dist\,\{d_1{:}P_{m1}\},\ dist\,\{d_2{:}P_{m2}\}\},$$
$$int\,\{dist\,\{d_1{:}P_{m1}\},\ dist\,\{d_3{:}P_{m3}\}\},$$
$$int\,\{dist\,\{d_2{:}P_{m2}\},\ dist\,\{d_3{:}P_{m3}\}\}\,) \quad (13)$$

In Equations 12 and 13, the operator *ave* is used to determine the mean position of the three intersections.

More complicated relationships such as the 'Parallel offset to line string, distance along the offset line' relationship (Figure 6.2) identified by Unkles' (1994) can be represented as:

<u>Distance along offset line</u>

$$P_s = dist\_line\,\{\,d{:}offset\_line\,\{\,o{:}\ L_m\},\ int\,\{offset\_line\,\{\,o{:}\ L_m\},\ angle\_to\,\{180^\circ{:}P_{m1},P_{m2}\}\}\} \quad (14)$$

where: d = the distance along the offset line.
o = the offset distance.

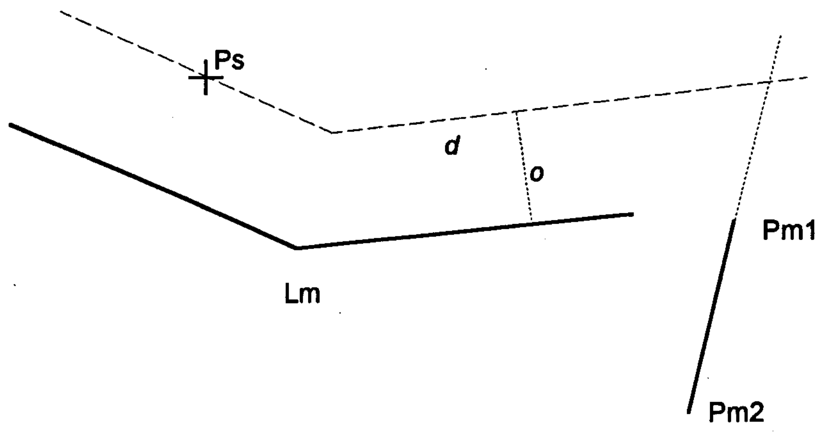

Figure 6.2 Distance along Offset Line. The position of the Slave point P_s is defined as being a distance *d* along a line which is at an offset *o* to the Master line L_m starting at the intersection of the line with a straight line passing through the Master points P_{m1} and P_{m2}.

Whilst these equations can be used in varying combinations to express many relationships, it is also necessary to develop a set of rules for their use. For example, in some cases it is possible that two elements in the one equation may give conflicting information about the position of a Slave feature. This will happen if relationships involving specific measurements are used in combination with a relative position, as occurs in the example in Figure 6.3.

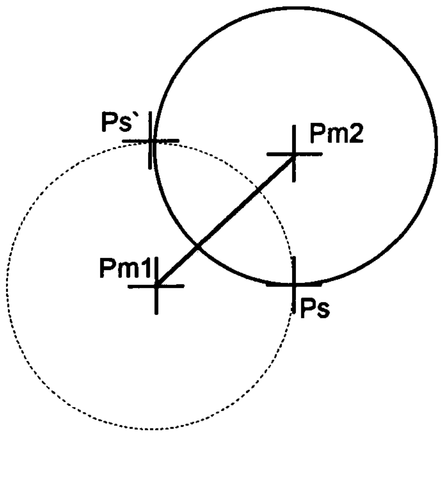

Figure 6.3 Two Distance Relationships and a Relative Position.

In Figure 6.3 the position of the point P_s has been determined using distance relationships. However, these relationships alone do not define a unique position for P_s. Hence a 'relative position' relationship with respect to the points P_{m1} and P_{m2} is used to identify which side of the line P_{m1}-P_{m2}, P_s lies.

However, the method used to represent a 'relative position' will give an incorrect position for P_S with respect to the two distance measurements. Therefore, whilst the 'relative position' can be used to determine the general position of P_S, the distance relationships should be used to determine this position more precisely. That is, whilst the two sets of relationships must be used together to determine a unique position, the position determined by the distance should take precedence once the relative position of the feature has been determined.

<u>2 Point Trilateration</u>

$$Ps = \text{int}\,\{\text{dist}\,\{d_1 : P_{m1}\}, \text{dist}\,\{d_2 : P_{m2}\}\} + \text{relpos}\,\{(P_{m1} : x_{m1}, y_{m1}) + (P_{m2} : x_{m2}, y_{m2})\} \qquad (15)$$

In order to use this technique for expressing positional relationships, it is necessary to be able to interpret these equations. Thus an essential part of the development of a system for managing positional relationships must include the development of an interpreter for the above equations. This interpreter will have two uses. They are:

1. Reconstructing an existing relationship, and
2. Testing the validity of a new relationship

The need to test the validity of a positional relationship is required as part of the process of creating an instance of a positional relationship within a user's GIS. It is necessary to test that the equation used to represent a particular relationship actually defines a unique position for the Slave feature. If it does not, then it will not be possible to reconstruct that relationship correctly and hence it will not be maintained if this should be required.

The process of creating relationships will be discussed in Section 6.6.

6.4.4 Summary

The purpose of this section was to identify and investigate the data required to successfully manage a positional relationship. It has been shown that these data are diverse and in one particular case difficult to ascertain. However, all data identified are essential if positional relationships are to be managed correctly.

The information identified is as follows:

- the features which have undergone a positional change;
- the nature of the positional change that has occurred;
- the features involved in a positional relationship;
- the place these features hold within the relationship;
- the class of the relationship;
- the form of the relationship; and
- the information required to reconstruct the relationship.

The above information must be stored, or must be able to be determined at the time of management, in order for a system to manage positional relationships to perform this function successfully. However, whilst these data are essential, it is also essential that an appropriate model for these relationships is developed. The development of such a model will be discussed in Section 6.5.

6.5 Modelling a Positional Relationship

One of the most important issues to be addressed, before developing a system to manage positional relationships, is to determine the way in which these relationships are to be modelled. That is, the method by which each positional relationship in the real world is to be represented within the GIS. The purpose of this model is to ensure that every relationship existing in the real world is represented in the GIS such that a positional change to a feature involved in one of these relationships can be detected and hence the relationship managed.

Given the requirements of this model, it must fulfil two tasks. Firstly, it must give an indication of which features are related and what place each of these features holds in the relationship. Secondly, it must indicate the nature of the relationship. That is, it must indicate the class and the form of the relationship.

The character of the model will be the basis around which the techniques to manage and reconstruct relationships will be developed. However, due to the natures of the database and object-oriented systems, it is not possible to use the same model in each system. The following sections therefore, will discuss the issues involved in developing a model for both of these systems.

6.5.1 Modelling Positional Relationships in an Object-oriented System

The nature of object-oriented systems is such that it is possible to include information about positional relationships as part of an object's characteristics. That is, rather than storing information about these relationships in a separate database, the information is stored as part of each individual object. One of the advantages of this is that it avoids the problem of linking records in a database to spatial features. However, the most important advantage is that it allows for the processes of managing these relationships to be completely automated.

Defining a model for positional relationships in an object-oriented system involves two processes. The first of these is to determine how to identify the related features. That is, should the Master features be related to the Slave feature or vice versa?

Whilst a feature may be involved in many positional relationships, it can only be a Slave feature in one of them. If this were not the case, it is conceivable that two relationships could result in conflicting positions for the same feature. Furthermore, it was shown in Chapter 4 that, whilst there may be many Master features in a positional relationship, there will only be one Slave feature.

Given these two facts about positional relationships, it seems sensible to relate Slave features to Master features since for each Slave feature it will be necessary to store information about only one positional relationship. This method has been used in the models developed by Wan (1993) and Kjerne and Dueker (1986).

Wan (1993) developed a method for modelling positional relationships in an object-oriented system. This method uses two types of point objects, a 'fixed point' and a 'moving point'. A fixed point is a point whose position is defined by a set of coordinates. The position of a moving point, on the other hand, is defined by its 'location rule'. That is, rather than storing a set of coordinates to represent the position of the point, the point's location rule is used to calculate the position with respect to some reference point. The position of this reference point is, in turn, defined by its particular location rule. Ultimately, every point is related via a series of relationships to a fixed point.

Two difficulties with representing positional relationships in this way can immediately be seen. They are the fact that some relationships involve more than one Master feature, and that some relationships involve line features. In Wan's model, line and polygon features are regarded as a series of straight line segments starting and ending with either a fixed or moving point. A relationship between line features, therefore, is actually represented by a set of point relationships. A solution to the problem of multiple Master features is to allow the location rule to include more than one reference point.

Unfortunately there is one other problem with Wan's model that is a little more difficult to solve. This problem occurs in the implementation of the location rule and the detection of positional changes.

The second process involved in developing a model for positional relationships in an object-oriented system, is to define the method by which the nature of the positional relationship will be represented. In Wan (1993) this nature is represented by the location rule. This rule is designed in such a way that it represents the position of the moving point. That is, whenever it is necessary to determine this position, the location rule calculates it with respect to its reference points.

The problem is that this method does not actually detect positional changes to the reference points. It simply recalculates the required position using the current positions of the reference points. This model of the nature of a positional relationship will not be able to manage these relationships correctly as it does not include information about relationship class and is unable to determine the type of positional change that has occurred. It can thus not determine the required action.

In Section 6.4.1.1 it was noted that the process of detecting a positional change to an object is relatively simple. The object itself is simply designed such that the act of changing its position will cause other processes to run. In order to manage a positional relationship therefore, two processes are required. Firstly, it is necessary to inform all related Slave objects that a change has occurred. Relationship management for these objects can then occur. Secondly, it is necessary to manage any relationship for which the subject object is a Slave feature. Each object therefore must have knowledge of all Slave features that are dependent upon it, as well as the fact that it is a Slave feature itself.

The location rule is the key to the object-oriented approach to managing positional relationships. This rule defines the nature of the positional relationship between the Slave and associated Master feature(s). In order for it to manage positional relationships correctly, however, it must be designed in such a way as to be able to fulfil the requirements of Section 6.2 as well as store, or be able to calculate, the information identified in Section 6.4. That is, it must:

- be able to detect the type of positional change that has occurred;
- have knowledge of the class of the relationship; and
- have knowledge of the form of the relationship and be able to use that information in order to reconstruct it correctly.

Thus, with careful design, it is possible to develop a model of positional relationships such that the object-oriented approach can be used successfully to manage all positional relationships within a GIS. The model developed here can be summarised as follows:

- All objects have knowledge of the positional relationships for which they are Master features. Thus, knowledge is in the form of the name of the Slave feature for those relationships. On detecting a positional change to itself, these Slave features are 'told' of the change such that management of the relationship can occur.

- Similarly, all objects have knowledge of any positional relationship for which they themselves are the Slave feature. In this case however, this knowledge is in the form of data that gives the class and form of the relationship. On detecting a positional change to itself, or on being told that a related Master feature has undergone a positional change, this information is used to manage the relationship.

The model above is just an example of a number of possible methods for modelling a positional relationship in an object-oriented system. In another example, the objects could be designed in such a way that the first task, on detecting a positional change, is to determine the form of that change. This information is then broadcast at the same time as the Slave features are informed that the change has occurred. The management process would then not need to determine this form.

A further refinement for the above model would be to allow line objects to have the same behaviour as point objects. This would then remove the need to represent relationships involving lines as a set of point relationships.

6.5.2 Modelling a Positional Relationship using the Database Method

Modelling a positional relationship in an object-oriented system is a relatively simple task. Unfortunately this is not the case when using the database method as it is not possible to represent a positional relationship as part of object behaviour. Rather, features are related using information stored in one or more database tables, referred to in this thesis as the Table of Relationships. That is, for every instance of a positional relationship in a GIS, there must exist information about that relationship in a database. This information can then be used to determine those relationships that have been affected by a particular positional change and the method required to correctly manage them.

The difficulty in developing a model for representing positional relationships using the database method is that, in order to fulfil Criteria 6.2.2, the definition of the database table must not be relationship specific. Rather, it should be standard for all relationships.

It has been shown that the information necessary to determine the required action after a positional change includes: the type of change that has occurred;

the class of the affected relationship; and the place of the affected feature within that relationship. Thus, it will be necessary to include, as part of the model, class information as well as information about the Slave and Master features. However, storing information about these features raises a small problem. That is, whilst there will only be one Slave feature in any relationship, the number of Master features will be dependent upon the relationship type. Therefore the number of Master features to be stored in the Table of Relationships will be dependent upon the relationship.

One possible solution to the variable number of Master features is to divide each relationship into a series of Slave/Master pairs. Thus, a relationship involving more than one Master feature would actually be represented as a set of positional relationships, each with the same Slave feature.

The 'heart' of the database method is the Table of Relationships. This table is similar to the location rule used in the object-oriented method, in that the information stored within it must be able to be used to determine the correct action after a positional change. However, unlike object-oriented systems it is not possible to directly link the information in this table with particular features. As such, it must be defined in such a way that it is possible to identify the features involved in every relationship used within the GIS, and the positions of these features in that relationship. From previous discussions, it can be seen that it is essential to have the following information stored in this table.

1. Relationship Number - a unique identifier for every relationship in the GIS.

   This number is unique to every full relationship within the GIS. That is, each sub-relationship, which forms part of another relationship (ie. a relationship involving line features or multiple Master features) has the same identifier.

2. Slave Point feature - the unique identifier of the Slave point feature as it exists within the GIS.

3. Master Point feature - the unique identifier of the Master point feature as it exists within the GIS.

4. Form of Relationship - the equation for the particular relationship.

Whilst not used in determining what action to take, it is necessary to know the form of the particular relationship in order to determine how to calculate the correct position of a Slave feature. This equation **must** define a unique position for the Slave feature as was discussed in Section 6.4.3.

5. Relationship Class - the class of positional relationship.

The model developed above is relatively simple and by no means the only possible model that can be used when implementing the database method. It does, however show the information required by the model as well as possible solutions to the problems of representing relationships with many Master features.

Unkles (1994) developed a spatial database whereby the position of a spatial feature (point or line) is defined, not necessarily by a set of coordinates, but by the method by which the data were originally captured. Thus, if the position of a feature was captured using GPS technology, then a set of coordinates is stored. However, if this position was determined using a bearing and distance to some other feature, then this bearing and distance information is stored. Each possible positional relationship has an associated database table in which the information required to maintain instances of that particular relationship is stored.

This method is similar to the object-oriented approaches suggested by Kjerne and Dueker (1986) and Wan (1993). However, it cannot be used alone to fulfil all the requirements of Section 6.2, as each database table is dependent upon the relationship type. The model cannot be used to manage any positional relationship unless such a table exists.

The model used for representing positional relationships in a GIS is fundamental to the correct management of these relationships. Therefore, it must be defined in such a way as to fulfil the requirements developed in Section 6.2. In closed systems such as that developed by Unkles (1994), it is possible to develop models which are relationship type specific, however, such models are not readily adopted by other users and also require complete reorganisation of spatial data. The methods suggested here however, are generic in nature and can be implemented on existing databases.

6.6 Implementing a Positional Relationship Management System

The previous sections of this chapter have discussed a number of the functional and data requirements of a system to manage positional relationships. Section 6.2 developed a set of criteria for such a system based upon the findings of Chapters 3, 4 and 5. Section 6.3 reviewed each of Hebblethwaite's (1989) maintenance techniques, introduced in Chapter 2, and found that only the database and object-oriented approaches were capable of fulfilling the requirements of Section 6.2. In Section 6.4, the data required for correct management of a positional relationship was discussed. It was found that information about positional changes (Section 6.4.1), the nature (class etc) of a relationship (Section 6.4.2) and the form of a relationship (Section 6.4.3) were all required. Finally, in Section 6.5 the issues involved with representing positional relationships within a GIS such that they can be identified and managed were discussed.

This final section will concentrate on the issues involved in integrating the requirements identified in these previous sections, into a system which can be used to manage positional relationships in a local government GIS. These issues include such things as:

- how instances of individual relationships are established within the system;
- how the currency of the relationship information is to be maintained;
- how the processes involved in managing a relationship are implemented; and
- how a relationship is to be extinguished.

The purpose for these discussions is to highlight a number of the issues which must be addressed whilst implementing a management system.

6.6.1 Establishing a Positional Relationship

Whilst the majority of this chapter has concentrated upon the management of positional relationships and the requirements of techniques to perform this function, there is little use for such techniques if these relationships are not represented within the GIS. That is, if the data necessary to manage them have not been collected. Therefore, the establishment of a positional relationship is an essential task if that relationship is to be managed.

6.6.1.1 Collecting the Relevant Data

The process of establishing a relationship, on the surface, appears a trivial task. It is simply a process of collecting that information necessary for determining the nature of a relationship as well as for reconstructing it. This information is then stored in the Table of Relationships and any associated tables, if using the database method, or as part of an object's characteristics, if using an object-oriented system.

However, the collection of this information can be complicated. This is due firstly to the fact that the information required will differ between relationship types, and also because a great deal of this information must be provided by the user. That is, apart from determining what features may have been added to, or removed from a particular data set, there are few, if any, reliable methods for automatically determining what these features may be related to and what the nature of that relationship might be. The user must be asked to provide this information.

The process of establishing a relationship involves collecting and storing the following information:

- the Slave Feature Identifier;
- the Relationship Class;
- the Relationship Equation;
- all Master Feature Identifiers; and
- all Relationship Specific Data (distances, angles, etc.).

The collection of information about the class and form of a relationship, and the name of the Slave feature, can be performed using a common process. However, it was noted in Section 6.4.2 that the number and nature of Master features in a relationship, and the information required to reconstruct a relationship, will be dependent upon the form of the relationship itself. Thus, in order to collect this information for any possible positional relationship, it is necessary that the system be able to interpret the relationship equation and hence determine what information should be collected.

The process of establishing a relationship can therefore, be complicated. It is further complicated by the fact that a user may wish to create a relationship using part of a feature. That is, it is possible that one feature may have a relationship with only part of another feature. For example, a user may wish to create a relationship between two line features, whereby the Slave feature is coincident with the Master line for only part of its length. An example is shown in Figure 6.4.

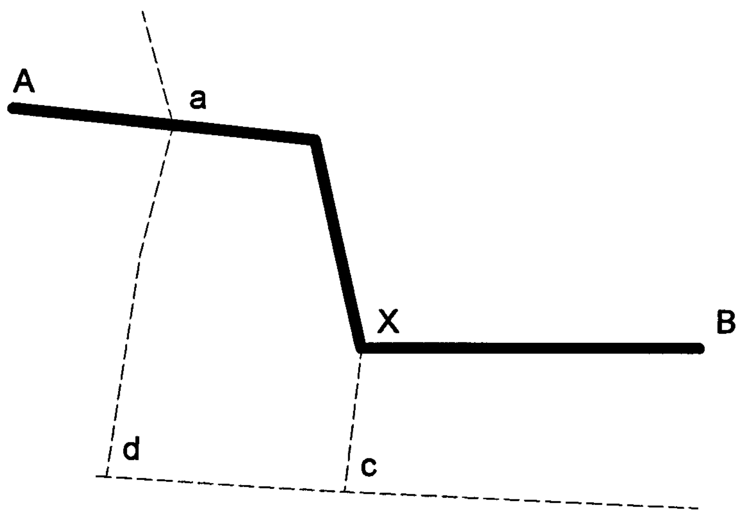

Figure 6.4 Partial Coincidence. The line **a-c** (dashed) is related the line **A-B** (bold) such that they are coincident between the points **a** and **X**.

If such relationships are to be expressed as combinations of the fundamental positional relationships, it may be necessary to develop a technique for identifying parts of features. The simplest solution to this problem however, is to split the features into parts such that those parts of the feature which are fully involved in the relationship are unique features. Thus, in the example in

Figure 6.4, the line **A-B** would be split into three lines **A-a**, **a-X** and **X-B**. Similarly, the line **a-c** would be come **a-X** and **X-c**.

A system to establish relationships should include the ability to cope with partial relationships. If these relationships are to be represented by the splitting technique outlined above, then this process should be able to introduce point features into existing lines. It should also amend any identifiers of these features such that the original line is still recognised as being a single entity.

6.6.1.2 Testing a Relationship

Whilst the main tasks involved in establishing a relationship involve the collection of the information required to manage and reconstruct that relationship, there is one other function that must be performed. It is essential that the relationship equation be tested to ensure that it gives a unique position for the Slave feature. If it does not it will be impossible to reconstruct the relationship when required.

There are a number of techniques used to determine the position of a feature which will not give a mathematically unique position. For example, two distances to the same point measured from two different points will actually give two positions for the Slave feature. It is necessary to ensure that these relationships, which give ambiguous results, are not allowed within the system.

6.6.1.3 Storing the Information

Once all the information required has been collected and tested it is necessary to store that information according to the model used (see Section 6.5). Thus in the case of an object-oriented model it is necessary to amend each Master feature such that it has knowledge of the related Slave feature, and it is necessary to amend the Slave feature such that the location rule becomes part of that feature's characteristics. If the database method is being used it is necessary to store the required information in the Table of Relationships.

6.6.1.4 Summary

The establishment of positional relationships is a complicated yet essential process. Figure 6.5 summarises this process.

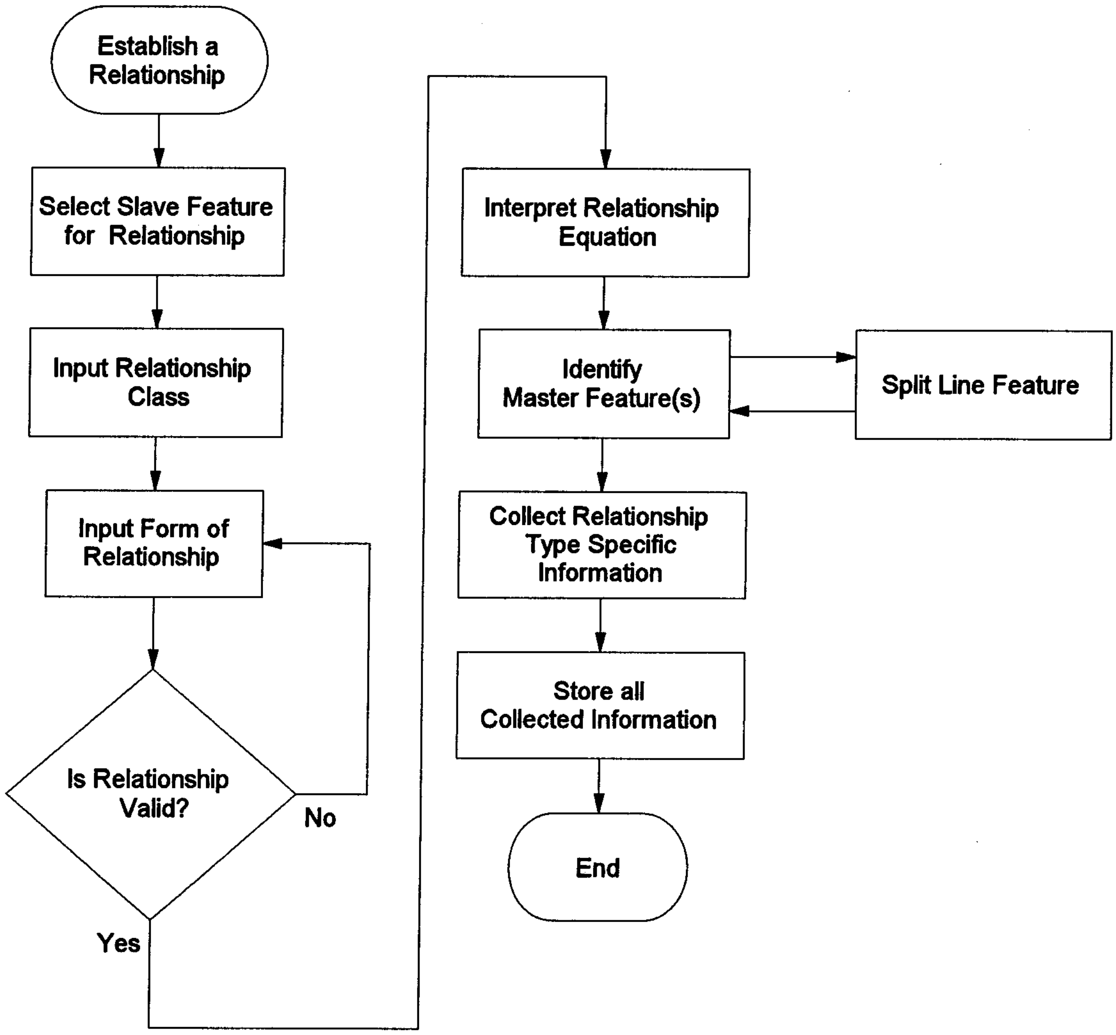

Figure 6.5 Establishing a Positional Relationship.

6.6.2 Managing a Positional Relationship

It was noted at the beginning of Section 6.4 that the process of managing positional relationships basically involves the following steps:

1. Detect a positional change to a feature and determine its form (update or upgrade);
2. For each positional relationship affected by this change determine the appropriate action; and
3. Perform that action.

Thus a management system will simply perform these functions. However, before such a system can be designed a number of questions need to be answered. These include:

- When will the process be used?
- How will the stored data be maintained?
- How is the 'rules base', developed in Section 6.4.2, to be implemented?
- How are the required actions to be performed?

The following sections will therefore discuss some of the processes required for a system to manage positional relationships.

6.6.2.1 Detecting Positional Changes

In order to manage positional relationships it is first necessary to identify those relationships requiring management. The common factor relating these relationships will be the fact that at least one of the features involved in them will have been affected by a positional change. Thus, the first step in the management of a relationship is to detect these positional changes.

Section 6.4.1 discussed a number of techniques for detecting positional changes in both object-oriented and layer based GIS. It noted that the data required from this process are the name of the feature affected and the form of the change. It is therefore not necessary to discuss these issues again.

However, one subject, which has not been covered, relates to how to use this information when using a database solution.

It was suggested in Section 6.4.1 that, when using the object-oriented system, objects can be designed in such a way that the act of changing an object's position will cause the processes managing that relationship to be performed. Unfortunately, features in a layer-based system can not be designed to automatically cause this to occur. Thus it is necessary to decide how the processes of managing relationships will be enacted. Two possibilities exist.

1. Management as a change is detected.

The first approach is to manage a relationship as soon as a change to a feature involved in that relationship is detected. That is, the process of detecting changes is integrated with the management process.

2. Management after all changes are detected.

This second approach separates the detection and management processes. The process of detecting changes simply tests a data set and stores the required information about all positional changes in an associated database. The management process can then be performed at any time using this data.

Both techniques have advantages and disadvantages which will not be discussed here. However, the choice of technique may have an affect on other parts of the management process.

6.6.2.2 Identifying a Relationship

Once a positional change has been detected, it is necessary to identify those positional relationships that have been affected by this change. Once again, this is a relatively simple task when using an object-oriented system as the objects themselves have knowledge of the relationships in which they are involved.

In the case of the database method, this information is determined by selecting, from the Table of Relationships, all those relationships involving the affected feature as either a Master or Slave feature. This process is summarised in Figure 6.6.

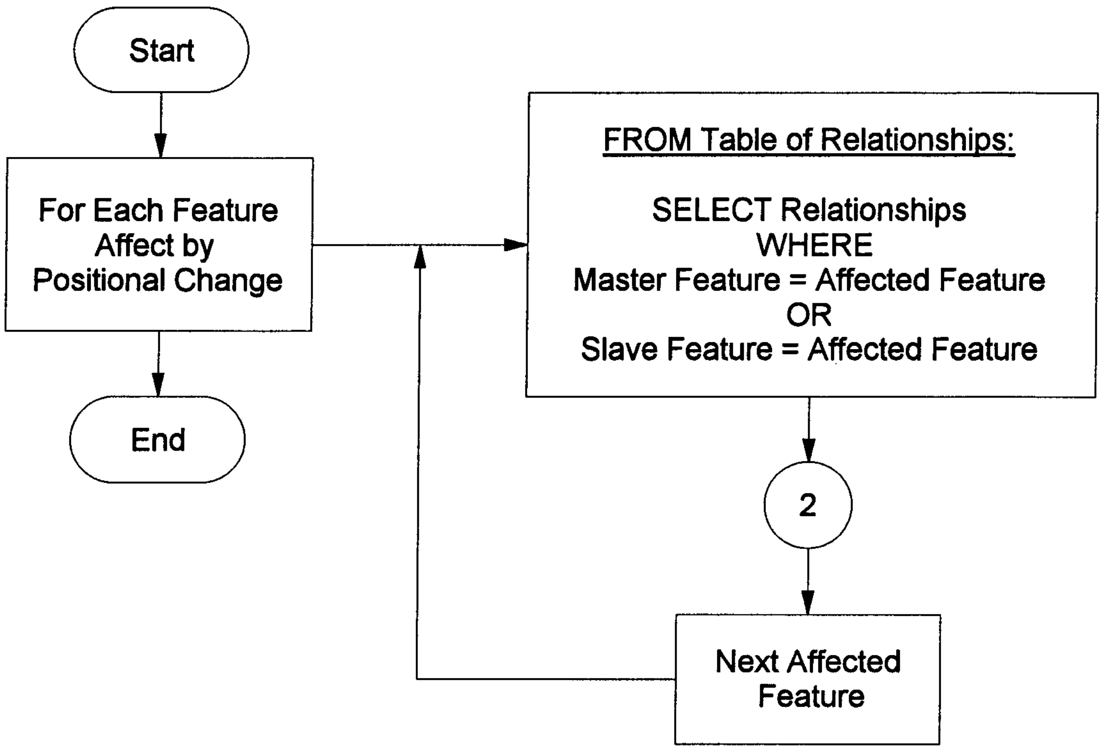

Figure 6.6 Selecting Relationships.

6.6.2.3 Determining the Required Action

In Section 6.4.2 the required action, with respect to a positional relationship after a positional change has occurred, was discussed. Table 6.2 showed that this action is dependent upon the type of change that has occurred, the place the affected feature holds within the relationship, the class of the relationship and, in some cases, the current status of the features within the relationship (ie. their relative positions). It was further suggested that this set of rules must be included in a system to manage positional relationships, if these relationships are to be managed correctly.

However the rules developed in Section 6.4.2 are applicable only to individual relationships (eg. one distance, one line offset, etc). They are not designed for the combinations of relationships which may be used. Thus determining the correct action to take with respect to these combinations is somewhat more complicated than simply applying these rules. Rather, it is necessary to apply the rules to each component part of the combination.

There are a number of ways in which the rules developed in Section 6.4.2 can be used to determine the correct action to take with respect to a relationship combination. Following is just one possible method.

The first step in determining the required action is to determine the current status of the Slave feature. Table 6.2 suggests that if this feature has undergone an update then the relationship should be extinguished. This process is summarised in Figure 6.7.

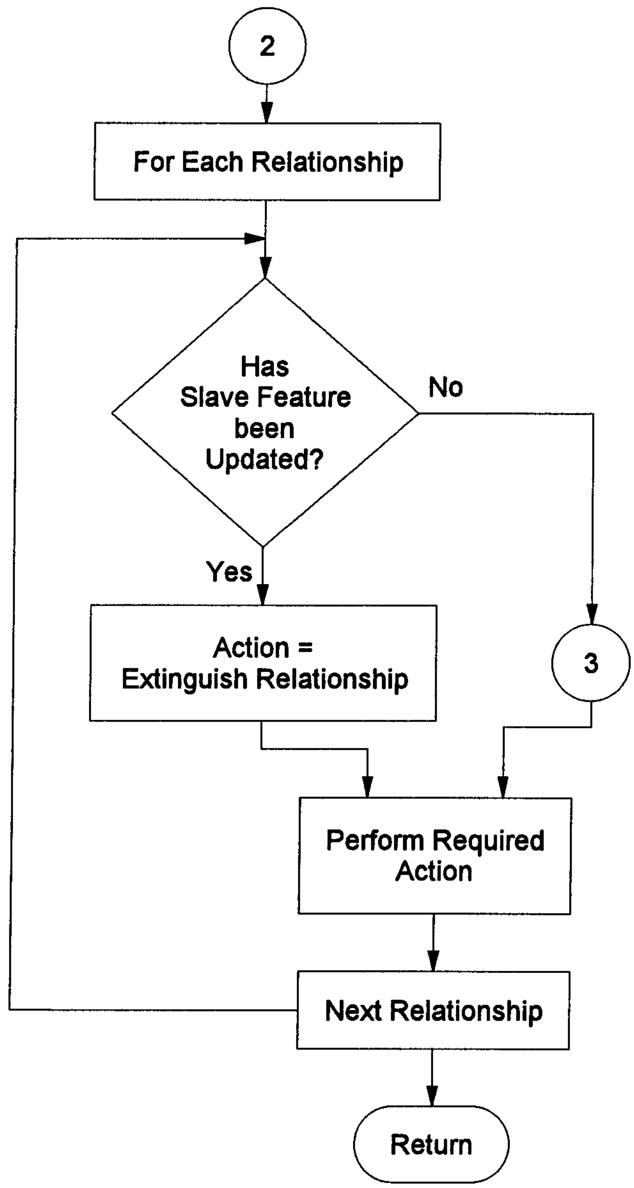

Figure 6.7. Determining the Required Action.

If the Slave feature has not been updated the next process is to determine if any of the Master features within the relationship have undergone an update. Thus the current status of each Master feature within the combined relationship is tested.

If an updated Master feature is detected, it is necessary to determine an action for any sub-relationships to which this feature belongs. That is, it is necessary to apply the rules base to each of these sub-relationships. This is done by performing a number of tests upon the sub-relationship and the combined relationship.

The first of these tests is to determine the class of the combined relationship. If it is a measured relationship, then the fact that a Master feature has been updated implies that the sub-relationship is no longer valid and hence should be extinguished. This does not mean that the combined relationship has become invalid. This will be determined with further testing. Rather, the combined relationship should be rewritten such that it does not include this particular sub-relationship.

The process of rewriting the combined relationship can be viewed as establishing a new relationship. Hence it is important to determine whether the new relationship equation is valid. If it is then the management process must continue. If it is not then the combined relationship has become invalid and should be extinguished.

If the combined relationship is a defined relationship then a further test must be applied to the sub-relationship. This test is based upon the form of the update that has occurred. It will be noted from Table 6.2 that, in cases of defined relationships, if an update has resulted in a Master feature being deleted, then the required action is to extinguish the relationship. Thus the same process as for a measured relationship is followed. However, if the update has resulted in the Master feature moving, then it is necessary to maintain the relationship. Hence the required action, at present, is to maintain the combined relationship. This action may however be revised depending upon the changes to other features in the combined relationship.

Figure 6.8 summarises the processes described above.

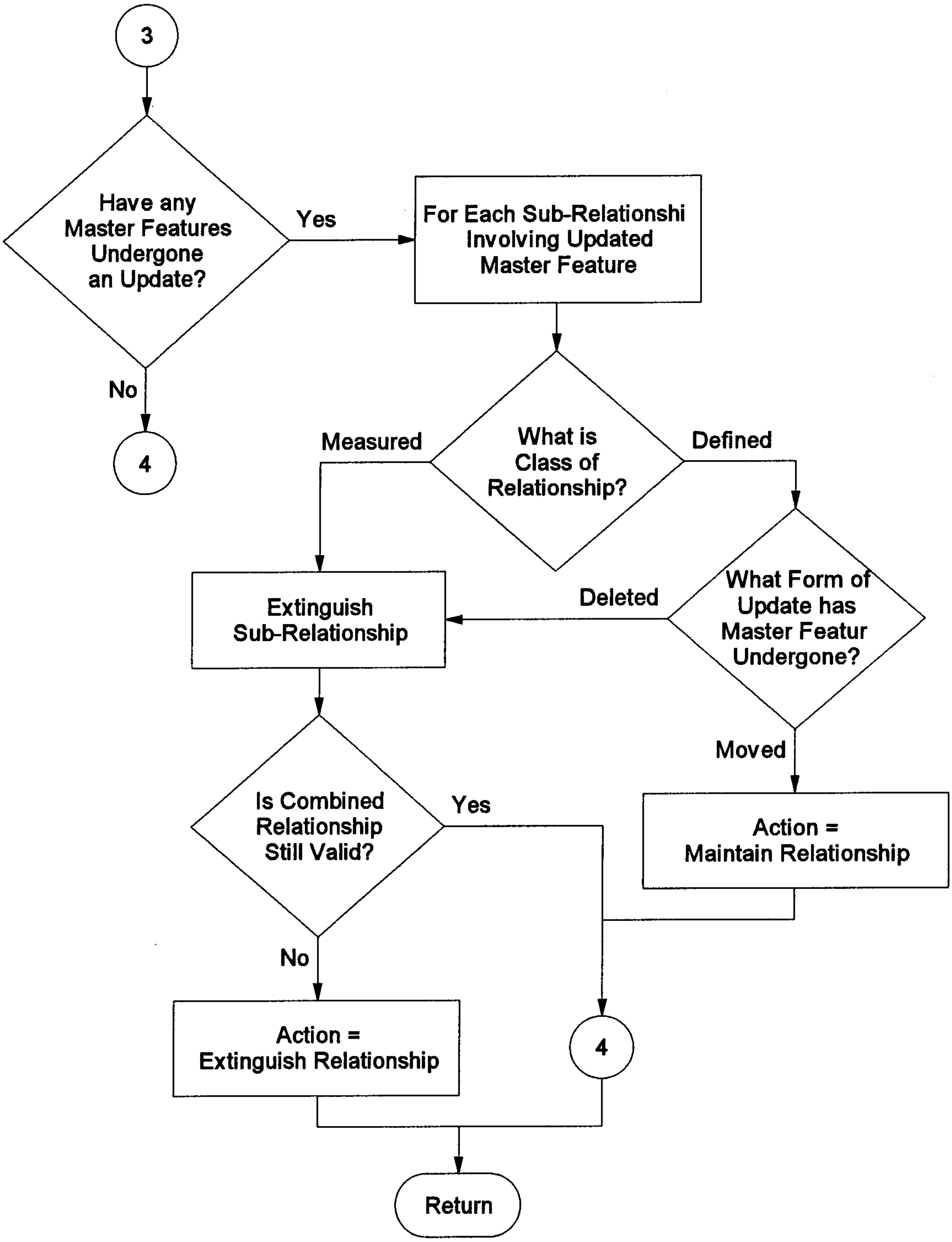

Figure 6.8. Determining the Required Action if a Master Feature is Updated.

If it has not been decided in the previous section to extinguish the relationship, the next process is to determine whether any Master features involved in the relationship have been upgraded. Unlike the previous section however, the process involved if any such changes are detected is relatively simple. The action required, at this point, is to maintain the combined relationship. This process is summarised in Figure 6.9.

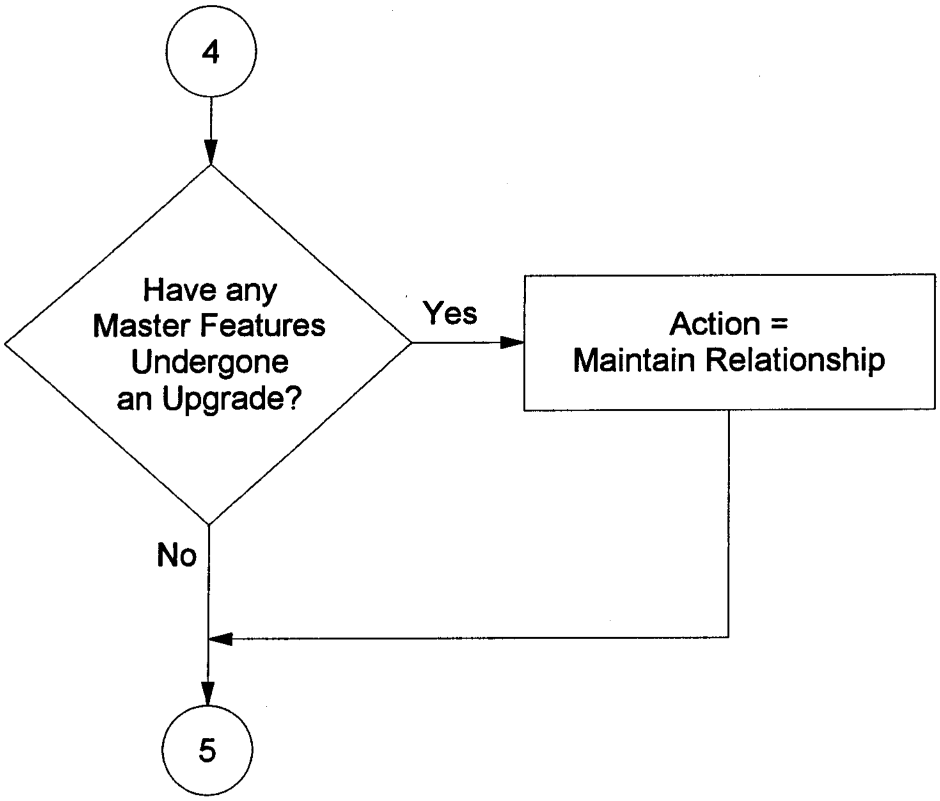

Figure 6.9. Determining the Required Action if a Master Feature is Upgraded.

The final step in determining the required action is to test the current status of the Slave feature with respect to upgrades. In Section 6.4.2 it was noted that an upgrade to a Slave feature might have occurred as a result of a positional relationship having been managed. Thus it is necessary to allow for this by testing whether an upgraded Slave feature is in its correct position. If it is then the required action is to simply do nothing with respect to the relationship.

If the Slave feature is not in its correct position, it is necessary to test the class of the relationship. Table 6.1 suggests that measured relationships should be extinguished. However, in the case of a defined relationship having undergone an upgrade, it is necessary for the user to determine the required action.

Figure 6.10 summarises this process.

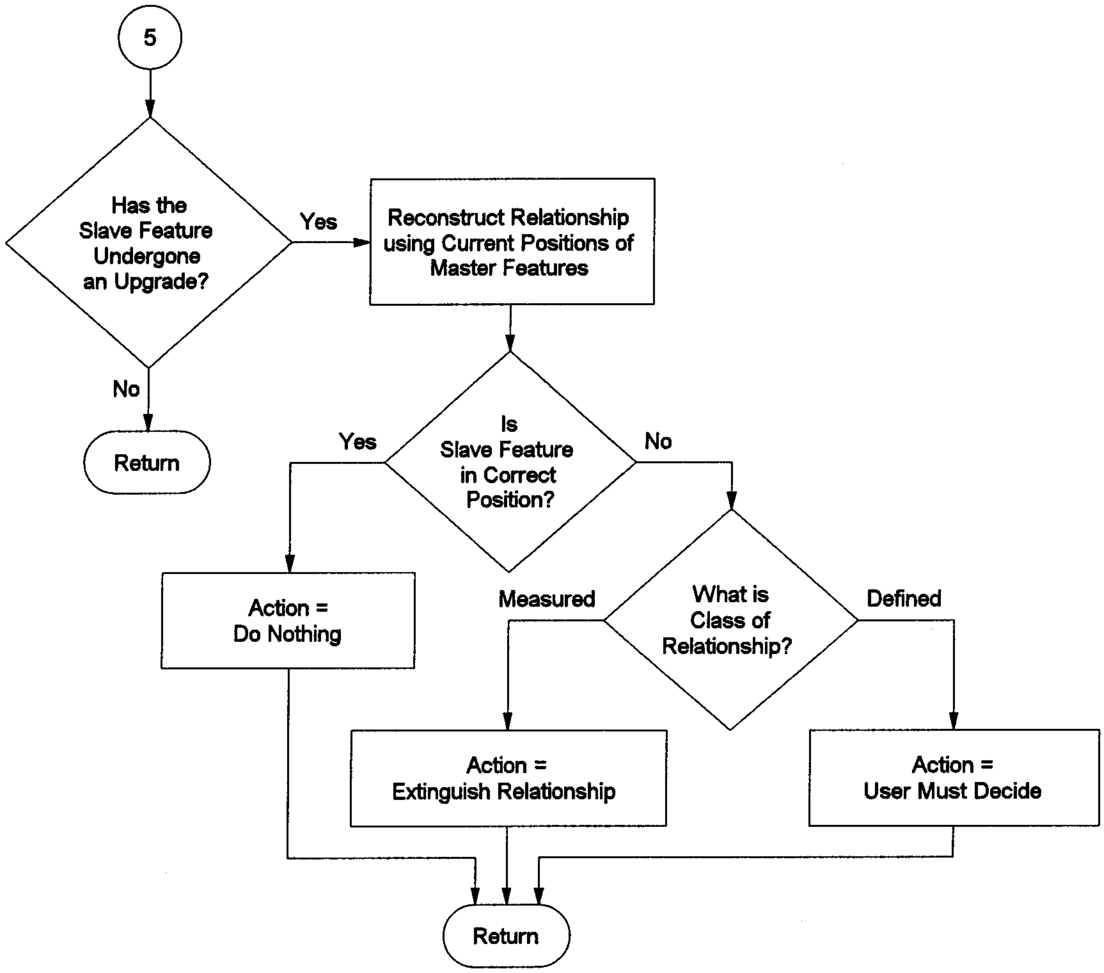

Figure 6.10 Determining the Required Action if a Slave Feature is Upgraded.

These processes show that a certain hierarchy exists with respect to the required actions. That is, the decision to maintain a relationship will only be taken if the decisions to extinguish or do nothing have not been made.

Once this action has been determined however, it is necessary to perform that action. The processes involved will be discussed in Section 6.6.2.4

6.6.2.4 Performing the Required Action

The processes of determining the required action, described in Section 6.6.2.3, show that four possible actions may be required. They are:

- Maintain the relationship;
- Extinguish the relationship;
- Define a new relationship; or
- 'Do Nothing'.

The process of defining a new relationship was discussed in Section 6.6.1 and the process of 'doing nothing' is self explanatory, hence they will not be discussed further. It is however, necessary to discuss the other two actions.

6.6.2.4.1 Maintaining a Relationship

Should it be decided that a relationship is to be maintained, a number of tasks should be performed before actually upgrading the Slave feature.

1. Determine the correct position for the Slave feature.

   This is done by interpreting the relationship equation and calculating the correct position of the Slave feature with respect to its Master features. This calculation is performed using the functions developed for each of the fundamental positional relationships.

2. Test for internal relationships.

   Criteria 6.2.6 requires that the maintenance process be aware of internal positional relationships. It is important to ensure that the act of upgrading the position of the Slave feature will not jeopardise the integrity of the data set by contradicting one of these relationships.

3. Reposition the Slave feature.

   Once it has been determined that it is safe to continue, the Slave feature is upgraded to its correct position.

The process of maintaining a positional relationship is summarised in Figure 6.11.

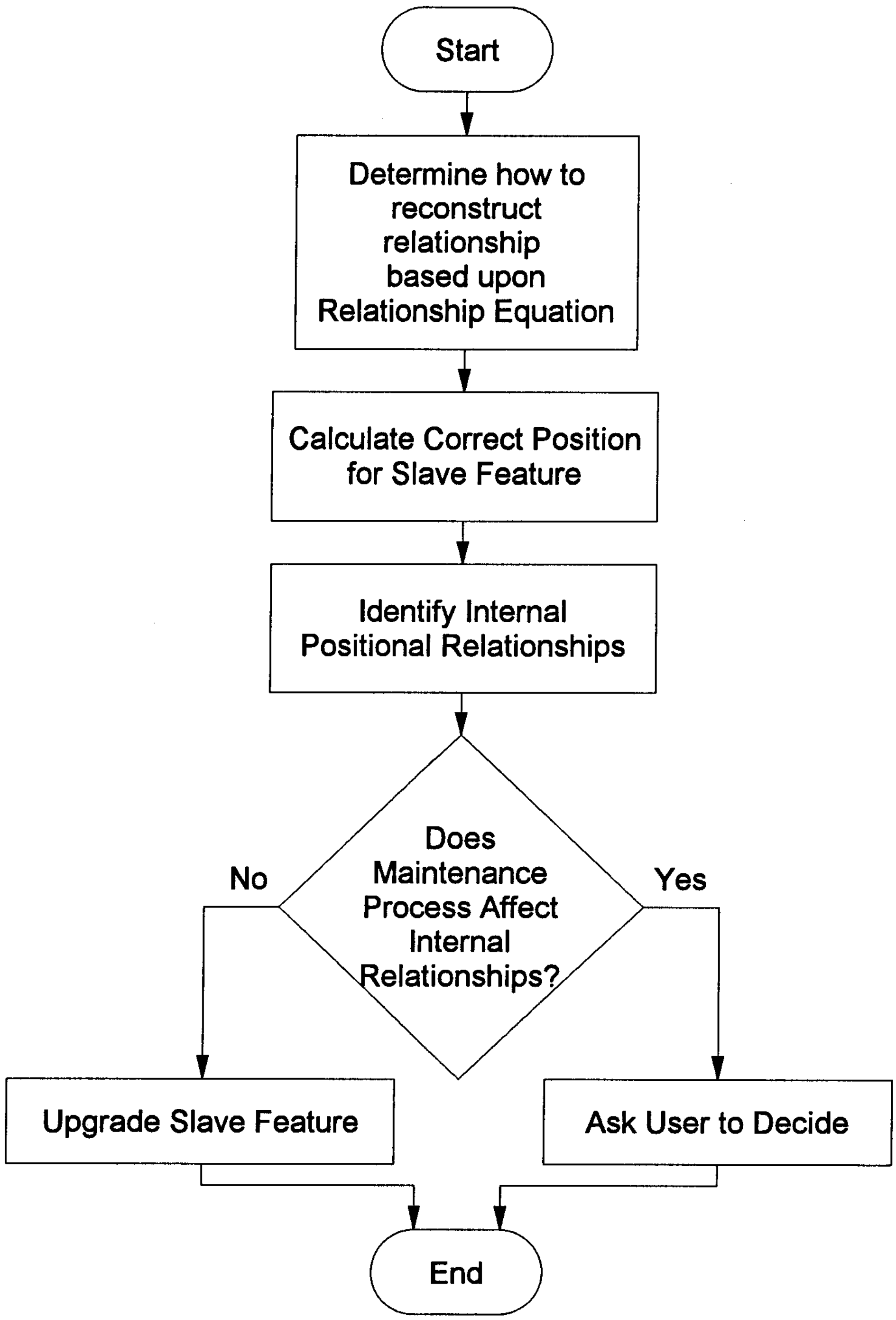

Figure 6.11 Maintaining a Relationship.

6.6.2.4.2 Extinguishing a Relationship

There are two possible methods for extinguishing a positional relationship. Firstly, all records of the relationship could be removed from the system. It would then appear that the relationship had never existed. Secondly, each relationship could be given a status (active or inactive) and value of this status changed depending upon whether the relationship is in use or not.

The use of the first method means that no history of the extinguished relationship would be maintained. There would be no way for determining which relationships had been extinguished after this had been done. It is possible that it may be necessary to have this historical information maintained within the system. Hence, the second method for extinguishing a relationship seems more appropriate.

The process of extinguishing a relationship is much simpler than maintaining it. It is summarised in Figure 6.12.

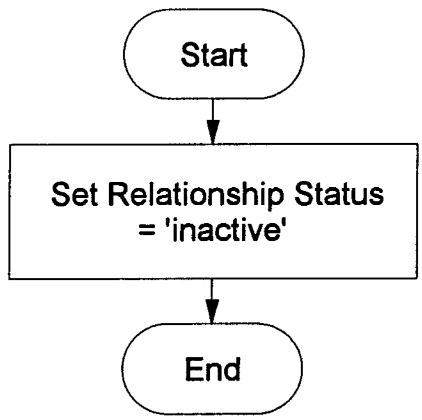

Figure 6.12 Extinguishing a Relationship.

6.6.3 An Example Implementation

The processes described in this section are best illustrated by an example.

The following example looks at a small section of a cadastral database. This section includes features to which features in other data sets are related via positional relationships. The example will demonstrate the processes involved in managing these relationships after certain positional changes have occurred. A database approach is used to manage the relationships.

6.6.3.1 The Original Data

Figure 6.13 shows the original cadastral data along with two other spatial data sets: a typical utility data set (Stormwater Network) and an administrative data set (Electoral Boundaries). In each case the positions of features in these other sets have been determined or defined with respect to cadastral features. For example, the positions of certain junctions in the stormwater network have been determined using bearing and distance measurements to nearby cadastral corners whilst the electoral boundary has been defined as being coincident with the cadastre. Thus both Measured and Defined positional relationships exist.

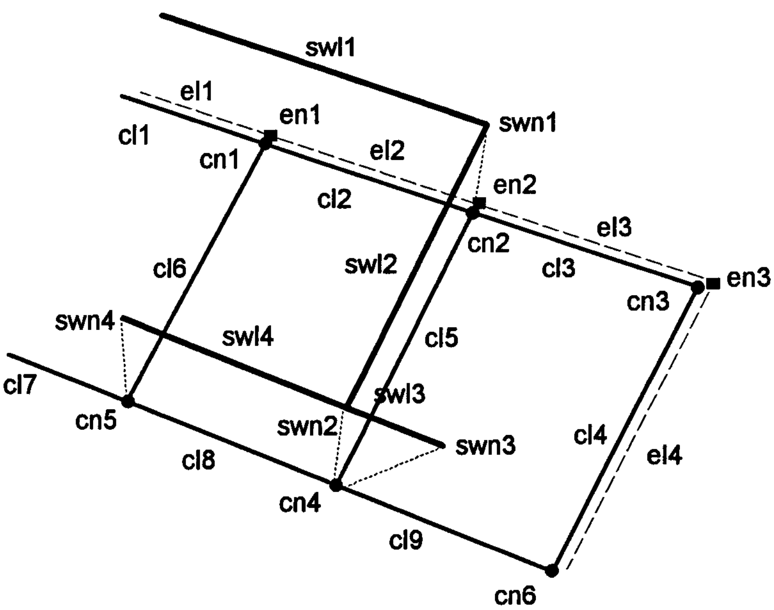

Figure 6.13 The Original Data. The stormwater (bold) and electoral (dashed) data sets contain features which are related, via positional relationships (dotted) to features in the cadastre (normal line).

In order to simplify the example, the electoral boundary has been split into individual features relating to each cadastral feature with which it is coincident. This avoids problems associated with relationships between parts of features as discussed in Section 6.6.1.1. Furthermore, every feature in each of the data sets has been uniquely identified.

Thus, there exist a number of positional relationships occurring between line and point features of varying forms. These relationships are listed in Table 6.3.

ID	Master	Slave	Class	Relationship Form
R1	cn1	swn1	Measured	int{dist{20:cn1},angle_to{95,cn1,Nth}}
R2	cn4	swn2	Measured	int{dist{5,cn4},angle_to{350,cn4,Nth}}
R3	cn4	swn3	Measured	int{dist{8,cn4},angle_to{300,cn4,Nth}}
R4	cn5	swn4	Measured	int{dist{4,cn5},angle_to{5,cn4,Nth}}
R5	cl1	el1	Defined	Offset_line{0,cl1}
R6	cn1	en1	Defined	dist{0,cn1}
R7	cl2	el2	Defined	Offset_line{0,cl2}
R8	cn2	en2	Defined	dist{0,cn2}
R9	cl3	el3	Defined	Offset_line{0,cl3}
R10	cn3	en3	Defined	dist{0,cn3}
R11	cl4	el4	Defined	Offset_line{0,cl4}

Table 6.3 The Table of Relationships. Each relationship is represented by the Master and Slave features involved, the Relationship Class and an equation for the Form of the Relationship.

6.6.3.2 An Example Update and Upgrade

The positional changes used for this example are typical of the changes occurring regularly in the databases maintained by many local governments. In this case, the cadastre at the point cn3 is splayed as shown in Figure 6.14.

In order to carry out this change in the real world, the entire cadastral parcel surrounded by the lines cl3, cl4, cl9 and cl5 was resurveyed. This survey found that the original information about the position of the line cl5 was incorrect. Thus this new information will also be added to the cadastral data.

In order to complicate the example, a change to the stormwater network will also take place such that the features swn3 and swl3 will be removed.

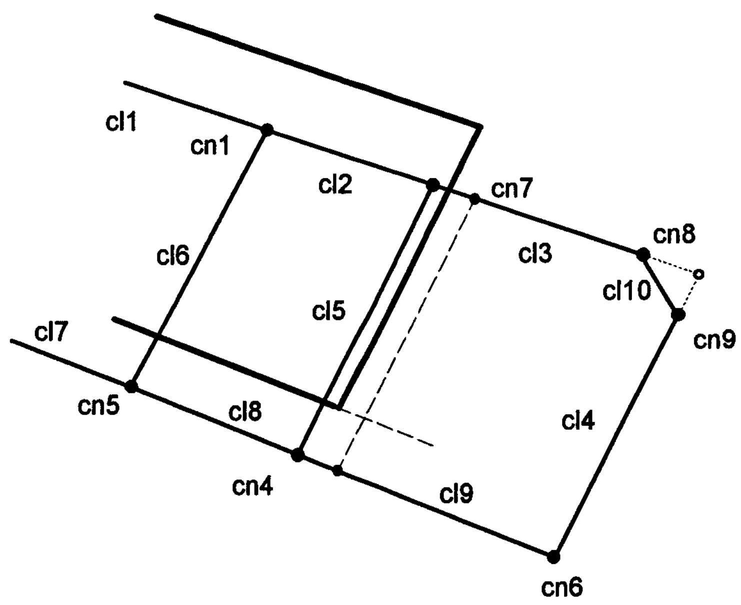

Figure 6.14 The Positional Changes. The corner at point cn3 has been splayed and two new points have been added (cn8, cn9). The position of the line cl5 has been upgraded. The line swl3 has been removed.

Assuming that all changes have been successfully made to the cadastral and stormwater databases, the first task necessary in the process of managing any affected positional relationships is to detect all changes between the old and the updated/upgraded information (Section 6.6.2.1). In each case, it is also necessary to detect the form of the change that has occurred. These changes are listed in Table 6.4

Feature	Type of Change	Affected Relationships
cl2	Upgrade	R7
cl3	Update – moved	R9
cl4	Update – moved	R11
cl8	Upgrade	None
cl9	Upgrade	None
cl10	Update – addition	None
Cn2	Upgrade	R8
Cn3	Update – delete	R10
Cn4	Upgrade	R2, R3
Cn8	Update – addition	None
Cn9	Update – addition	None
Swl3	Update – delete	None
Swn3	Update – delete	R3

Table 6.4 The Positional Changes. The features which have undergone a positional change, the type of change that has occurred and the relationship, if any, affected by that change.

As each change is detected it is possible, by referring to the Table of Relationships (Table 6.3), to determine any relationships affected by that change (Section 6.6.2.2).

For each relationship, affected by a positional change, it is now necessary to determine the required action and perform that action. Thus for Relationship 7, affected by an upgrade to the line cl7, the following process is followed:

Relationship 7:	Master Feature	cl2
	Slave Feature	el2
	Relationship Class	defined
	Relationship Form	offset_line{0,cl2}

Has Slave Feature been updated? No.

Has Master Feature been updated? No.

Has Master Feature been upgraded? Yes. Maintain Relationship

Has Slave Feature been upgraded? No.

The required action for this relationship is to upgrade the position of the slave feature such that the relationship is maintained. Thus the line el2 is moved such that it is coincident with the line cl2.

The required actions for each of the affected relationships is given in Table 6.5

Relationship	Required Action
R2	Maintain Relationship.
R3	Extinguish Relationship.
R7	Maintain Relationship.
R8	Maintain Relationship.
R9	Maintain Relationship.
R10	Extinguish Relationship. New Relationship may be required.
R11	Maintain Relationship.

Table 6.5 The Required Actions.

An interesting situation arises with the Relationship 9, 10 and 11. The required action for R9 and R11 is to maintain the relationship. These are both defined relationships and the change that has occurred in both cases is an 'update – move' to the master feature. In order to maintain these relationships however, it will be necessary to split two adjoining lines (el3 and el4). The user will be warned of this problem by the fact that the required action for Relationship 10 is to extinguish the relationship involving the delete point cn3 and, as it was a defined relationship, warn the user. In this case, the user will be required to update the electoral boundary such that it is coincident with the newly splayed corner.

Once all required actions have been fulfilled, all positional relationships will have been managed correctly and the user can be confident that the positional changes that took place have not degraded the quality of the spatial database. Figure 6.15

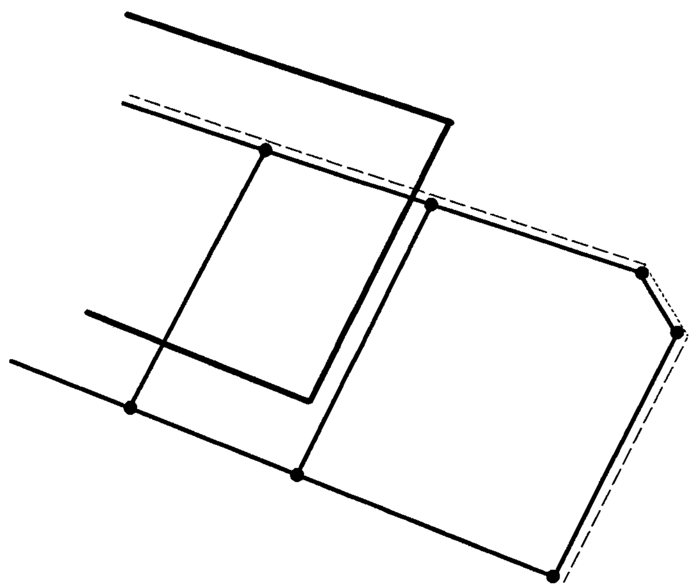

Figure 6.15 After Positional Relationships have been managed.

6.6.4 Summary

Implementing a system to manage positional relationships is not a simple process. This section has shown that it requires more than just implementing the set of rules developed in Section 6.4.2. Rather a management system must be able to:

1. establish relationships;
2. store relationship information;
3. detect different types of positional changes;
4. identify relationships by the features within them;
5. reconstruct relationships;
6. maintain relationships;
7. test the current status of relationships;
8. test the current status of features within a relationship; and
9. determine the correct action to take.

Given the complexity of these requirements and the fact that a solution to problems involved in performing Requirement 3 needs to be found, the amount of work necessary to develop a system to manage positional relationships would be tremendous. It is therefore not the intention of this thesis to develop and test such a system. This section is intended only to serve as a guide to those who have the resources available to carry out the tasks required after methods for detecting the form of a positional change has been developed.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Review of Thesis

The use of positional relationships to determine the positions of features in the real world has been occurring since before the development of computerised geographical information systems. Traditionally, they have been used by cartographers as a technique for creating maps. Hence, they play an important role in the collection of spatial information.

In the case of map making however, a positional relationship is simply used as part of the creation process. Thus, once the position of a particular feature has been determined and that feature placed within the map, the relationship information is discarded. The position of the feature is then represented by a set of coordinates which are implied in a paper map or stored in a digital map. The fact that a relationship exists between this feature and other features is no longer required and hence ignored.

Unfortunately, this method for making maps has continued into the GIS age. Thus, whilst positional relationships are still used to collect spatial information, once this information has been converted to a set of coordinates, it is discarded and only the coordinate set stored.

A problem occurs with this approach to the creation of a spatial database, if the custodian of this database wishes to change the positions of features within it. This may occur if a feature in the real world has moved (an update) or new information about the feature's original position has been acquired (an upgrade). It is possible that the positions of other features in other data sets may have been determined using positional relationships with these updated or upgraded features and that these relationships are still relevant. Thus the act of making this positional change may adversely affect the accuracy of the positions of these other features.

The problem of positional changes affecting the spatial integrity of other data sets has been recognised by a number of authors however the only solutions developed have concentrated upon maintaining relationships. Until the investigations described in this thesis, little, if any research has looked at whether maintenance of a relationship is required in all cases of a positional change.

This thesis has investigated the nature of positional relationships so as to determine how they might be used to improve the integrity of the spatial data stored within a GIS. This improvement would result through the ability to manage these relationships as positional changes occur to features within the GIS.

Local government was chosen as the subject for this study for a number of reasons. Firstly, the diversity of data used by these organisations is amongst the largest of all GIS users. Hence, it is likely that the number and diversity of positional relationships used to collect a councils' data would also be large. Secondly, this same diversity means that the results of the investigation can easily be adapted to other areas of GIS use.

The first step in investigating positional relationships was to identify and study the data sets used by local government (Chapter 3). This was done by examining the legislative responsibilities of councils in New South Wales as well as sending a questionnaire to a number of NSW councils. As expected, the diversity of data sets identified as being used by local government is large. It was found that any one council might keep asset data, utility data, transport data, environmental data, information about certain administrative boundaries and various survey based data. The most important of these data sets is the cadastre, which is used by many councils as a base to which features in other data sets are related. However, it was also found that this data set is dynamic.

Using the results of this investigation, it was possible to identify a number of different types of positional relationships that are used to create these data sets (Chapter 4). Once again, the diversity of these relationships is large. Whilst some relationships are based solely upon physical measurements, others are more abstract in nature. Some relationships exist between point features, others between line features, and yet others between combinations of points and lines.

Whilst studying these relationships, a number of important facts were discovered. Firstly, it was found that there are two distinct purposes for a which a positional relationship exists. This discovery resulted in the definition of a method for categorising relationships called the Relationship Class. The two classes of relationship identified are:

- Measured Relationships - the position of one feature has been determined at one particular time using measurements to nearby features.
- Defined Relationships - the position of one feature has been defined using relationships to nearby features.

Secondly, it was found that a relationship will involve two types of features. There will exist one or more features to which another feature is related (called Master features) and one feature whose position is dependent upon the positional relationship (called the Slave feature).

Finally, a set of fundamental positional relationships was derived. These fundamental relationships can be used by themselves, or in combination, to describe any positional relationship used in a local government GIS.

The reason that management of positional relationships is of importance to the GIS industry is that, unlike with paper maps, it is not difficult to make positional changes (updates and upgrades) to individual features represented within a digital spatial database. Therefore such changes can be, and are made at regular intervals. However, as mentioned previously, these changes have the potential to compromise the spatial integrity of other spatial data sets if the features in these data sets have been positioned using positional relationships.

Chapter 5 investigated the processes of updating and upgrading with respect to the effects they have upon different positional relationships. It was found that the form of a relationship played no part in determining this effect. Rather, the type of change that had occurred, the class of the relationship and the place the updated or upgraded feature held within the relationship (Master or Slave feature) all play a role in how a positional relationship will be affected by a positional change.

These effects are listed in Table 6.1 which is repeated below.

Form of Change	Feature Type	Relationship Class	Affect on Positional Relationship
Update - Moved	Master	Measured	Relationship becomes invalid.
		Defined	Relationship may remain valid
	Slave	Measured	Relationship becomes invalid.
		Defined	Relationship becomes invalid
Update - Deleted	Master	Measured	Relationship becomes invalid.
		Defined	A new Relationship should be defined.
	Slave	Measured	Relationship becomes invalid.
		Defined	Relationship becomes invalid.
Upgrade	Master	Measured	Relationship remains valid.
		Defined	Relationship remains valid.
	Slave	Measured	Relationship becomes invalid.
		Defined	Conflict of Positional Information. User must decide.

Table 6.1 (repeated). The Effect of Positional Changes on Positional Relationships.

Chapter 5 also noted that, often, the organisation responsible for making changes to spatial data is not the user of that data. Thus, these changes must be propagated to these users.

Using the results of the investigations in Chapters 3, 4 and 5, Chapter 6 discussed a number of the issues involved with the management of positional relationships. These discussions included:

- the development of a set of requirements for a positional relationship management system;
- a review of a number of the techniques proposed for maintaining relationships with respect to their ability to fulfil these requirements;
- the data needed for managing relationships;
- possible models for a relationship;
- the processes involved in the establishment and management of positional relationships; and
- a simple example of these processes in action.

7.2 Conclusion

The results of the investigations in this thesis have found a number of important facts about the nature of positional relationships as they are used by local governments. Furthermore, given the diversity of data used by local government, it is not unreasonable to apply these results to many other fields of GIS usage. These results include:

- the development of a classification of positional relationships based upon the purpose for the relationship.
- the development of a set of fundamental positional relationship which can be used to describe all other positional relationships.
- the development of a set of rules for determining the required action after a positional relationship has been affected by a positional change.
- the development of a set of requirements for a system to manage positional relationships in a GIS.

The management of positional relationships in GIS is gaining increasing recognition as being important for local government and utility industries. This is due to the following facts:

- Much of the spatial data used by these organisations contains features which are closely related;
- The features in some of these data sets are undergoing constant positional change;
- Some of these changes are having the effect of degrading the spatial integrity of data sets containing features which are related to these updated or upgraded features;
- If these relationships are not managed correctly, the spatial integrity of these data sets will, over time, become so severely degraded as to make them useless.

In recent times a number of organisations have expressed an interest in wholesale adjustments of various data sets. These organisations are interested in improving the spatial accuracy of their data (DNR, 1997) or matching vector data sets to aerial photography (North Sydney, 1996). In either case, the adjustment process will result in a great many features being upgraded. It is thus essential that these organisations be aware of the possible effects on other data sets if positional relationships between features in all data sets are not managed correctly.

It can and has been argued that the solution to the problems associated with positional relationships is simply to determine the position of everything to an accuracy far greater than that required. It would then not be necessary to have knowledge of relationships as the process of upgrading would not occur. This, of course is one possible solution, however two problems arise. Firstly, it will still be necessary to manage relationships in the case where features are updated as the need to maintain the currency of databases will still exist. Secondly, such an approach is completely impractical as governments, and especially local government, would never be able to afford the time or money required to survey all data required to an appropriate accuracy. Furthermore, some of these data, such as various environmental data sets, are inherently inaccurate.

The most important part of the process of managing a positional relationship is not the method used to maintain the relationship. Rather it is the ability to decide when a relationship should be maintained and how it should be maintained. If these decisions are not made correctly (or not made at all), then relationships will be maintained in instances where they should not be, and other relationships will be ignored despite the fact that they still exist in reality. As a result, inaccuracies will propagate throughout the spatial database and hence the spatial integrity of the database will be severely compromised.

As GIS and database software vendors move towards the development of 'spatial engines' and spatially enhanced databases, the need to be able manage positional relationships does not disappear. However, the development of system to manage them may be simpler. This generation of tools allows for spatial information to be stored in standard database structures. Thus, as the data are already in a database it may be possible to develop a management system around this data using database tools such as 'triggers'.

7.3 Recommendations

The next logical step in the development of a system to manage positional relationships is to actually develop a prototype system. However, before this can be done the problem of detecting the form of a positional change must be solved.

One of the most important processes required as part of a relationship management system is the ability to detect the form of a positional change. That is, whether an update or upgrade has occurred. This information is essential if relationships are to be managed correctly as it plays an important role in determining how a relationship will be affected by a change. Unfortunately, the detection of these changes is not easy and at present no simple solutions are obvious.

The problem with detecting the form of a positional change is that one of the requirements of a management system, developed in Section 6.2, is that the system should be independent of the processes of updating and upgrading. This is necessary so as to allow for management of relationships which include features in spatial data sets maintained and supplied to a user by an outside organisation. This requirement forces the detection process to rely on comparing new information with old. Thus the detection of different forms of positional changes can only be achieved if enough information is supplied so as upgrades can be differentiated from updates where a feature is moved. It was shown in Section 6.2 that the information required is more than just a unique identifier for each feature.

This problem, along with a lack of time and resources, have prevented a prototype system being developed here. However, using the findings of this investigation and a solution to the problem of detecting different types of positional change it will be possible to develop such a system.

This thesis has concentrated upon the nature and management of positional relationships between individual spatial features in separate vector data sets. It was found in the survey of local governments that raster data sets in the form of aerial photography are also commonly used. These data sets are commonly used as a backdrop for cartographic output. Thus it seems reasonable to expect that positional relationship will exist between the features in these images and features in other data sets.

The issues involved in the management of Model relationships have also not been discussed at length. It was noted in Section 6.4.3.1.9 that these relationships are different from other forms of positional relationship and hence do not follow the same rules. They are, however, important relationships and should not be ignored as all other positional relationships have been.

Finally the issue of internal positional relationships was raised as part of the development of the set of requirements of a management system. These relationships are simply positional relationships between features of the same type. Therefore it is probable that they can be managed using the same techniques used to manage all other positional relationships. Before this is done however, these relationships should be investigated in much the same way as external relationships have been investigated for this thesis.

As mentioned previously, positional relationships are an important tool for the collection of spatial information. To the present they have been largely treated by the GIS industry as being irrelevant after the data capture process. This thesis has shown that correct management of these relationships can be achieved in both traditional, layer based GIS and object-oriented systems with a little care and thought.

Failure to recognise the importance of positional relationships may never affect users of some spatial databases. These databases may be relatively static and the data may have been captured to an accuracy far greater than that required. However, for those users of spatial information which is dynamic, such as cadastral information, the management of positional relationships is extraordinarily important if these relationships have been used to position features in other data sets.

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APPENDIX A: THE LEGISLATIVE RESPONSIBILITIES OF LOCAL GOVERNMENT

> *The basic idea of local government is that people of a comparatively small and defined local community should govern themselves in all matters of local concern which affect their daily lives.*
>
> (Whitmore, 1981 p1.)

Local government is, technically, not the third tier of government in Australia. Rather, respective state governments define certain responsibilities for councils through various pieces of legislation. Thus, in order to determine the responsibilities of local government in NSW, it is necessary to look closely at this legislation.

In New South Wales, a number of Acts of Parliament have an effect upon the responsibilities of local government. The most important of these pieces of legislation is the *Local Government Act, 1993.*

A.1 The Local Government Act

In 1993, the New South Wales State Government repealed the *Local Government Act, 1919* and replaced it with a new Act. The *Local Government Act, 1993*, (*LGA, 1993*) provides the legislative basis for local government in NSW (White 1993 p371) detailing, amongst other things, how councils are formed, how and when council elections should be conducted, how councils are financed and, importantly for this study, many of the responsibilities and powers of councils with respect to the services and functions they carry out.

There are three key sections of the Act which have some bearing on this study. These are discussed in the following sections.

A.1.1 The Local Government Charter

Chapter 3 of the *LGA 1993* gives councils the following charter.

s.8(1) A council has the following charter:

- *to provide directly or on behalf of other levels of government, after due consultation, adequate, equitable and appropriate services and facilities for the community and to ensure that those services and facilities are managed efficiently and effectively*
- *to exercise community leadership*
- *to exercise its functions with due regard for the cultural and linguistic diversity of its community*
- *to properly manage, develop, protect, restore, enhance and conserve the environment of the area for which it is responsible*
- *to have regard to the long term and cumulative effect of its decisions*
- *to bear in mind that it is the custodian and trustee of public assets and to effectively account for and manage the assets for which it is responsible*
- *to facilitate the involvement of councillors, members of the public, users of facilities and services and council staff in the development, improvement and coordination of local government*
- *to raise funds for local purposes by the fair imposition of rates, charges and fees, by income earned from investments, and, when appropriate, by borrowings and grants*
- *to keep the local community and the State government (and through it, the wider community) informed about its activities*

- *to ensure that, in the exercise of its regulatory functions, it acts consistently and without bias, particularly where an activity of the council is affected*
- *to be a responsible employer.*

(2) *A council, in the exercise of its functions, must pursue its charter but nothing in the charter or this section gives rise to, or can be taken into account in, any civil cause of action.*

(LGA, 1993: in White, 1993)

Whilst not outlining any specific requirement for the use of spatial information, it can be seen that some of the responsibilities of local government outlined in this charter will require its use. The requirements to manage both the environment and public assets are excellent examples.

A.1.2 A Council's Functions

Chapters 5-8 of the *Local Government Act, 1993,* detail a number of the functions and services that councils are required to perform. These are divided into Service (Chapter 6), Regulatory (Chapter 7) and Ancillary Functions (Chapter 8).

Unlike the previous Act, the *LGA, 1993* changed the perspective of the powers and functions of councils by leaving it to individual councils to determine what services they will provide (Pearson 1994, p233). Thus, whilst certain responsibilities are prescribed by the Act, the wording of the Act is quite general and hence councils are given some freedom as to how they carry out these responsibilities. Sections 21-24 give individual councils the flexibility to perform those functions they feel are necessary to fulfil the charter (White, 1993, p1302). This is illustrated most clearly by Section 24.

s.24 A council may provide goods, services and facilities, and carry out activities, appropriate to the current and future needs within its local community and of the wider public, subject to this Act, the Regulations and any other law.

(LGA, 1993 in White 1993)

Such flexibility did not exist in the previous Act, which inferred the power to perform specific activities. Councils could not carry out functions not mentioned specifically under the Act.

In 1990, a white paper, known as the Local Government (Functions) Bill, listed many of the functions of councils implied by Section 24 (Pearson, 1994, p233). Examples of those functions of interest to this study include the provision, management or operation of:

- environment conservation, protection and improvement services and facilities;
- fire prevention, protection and mitigation services and facilities;
- land and property development;
- public reserves;
- public roads;
- public transport services and facilities;
- waste removal, treatment and disposal services and facilities;
- water, sewerage and drainage service facilities.

(Pearson 1994, p233-234 and White 1993, p1301.)

This is by no means an exhaustive list of the functions of local government However, it does show that there are a range of activities which councils perform for which the use of spatial information may be of some benefit. The spatial information needed, however, will be dependant upon how individual council chooses to perform these functions.

Certain sections of the Act actually require councils to maintain specific pieces of spatial information. One such section is Part 2 of Chapter 6 which deals with the management of public lands. Public lands are those lands vested in council and can be classified as either 'community' (parks, gardens, sporting fields, etc.) or 'operational' (council depots, water treatment plants, etc.). Part 2 requires each council to develop management plans for all community lands (Section 35) as well as to maintain a 'land register' of all public lands under its control (Section 53). This register covers both 'community' and 'operational' lands and must include, amongst other things, the location of the land. Whilst there is no requirement for councils to use GIS for this task, such technology could play an important role in carrying out these functions.

Councils also have a responsibility to regulate certain activities. These activities include such things as the erection of buildings, the use of community land, and the construction of water supply, sewerage and stormwater drainage works. Once again, spatial information could be invaluable for ensuring that these activities are regulated correctly.

Thus, it can be seen that the *Local Government Act, 1993*, requires councils to perform a number of functions for which the collection and use of spatial information could be important. It is not the function of the Act to specify the type of information to be used, nor does it specify how this information should be used. However, from the list of responsibilities it can be seen that a large range of data types may be required. This information may include such things as:

- environmental data;
- land use data;
- utilities data (water, sewerage and stormwater drainage); and
- cadastral data.

A.1.3 Financial Management and Annual Reports

As well as defining what services and functions councils can provide, the new Act also imposes new accounting and reporting requirements. Parts 3 and 4 of Chapter 13 of the Act deal with Financial Management (Part 3) and Annual Reports (Part 4).

Section 413(3) of the Act states that:

> *s.413(3) The general purpose financial report must be prepared in accordance with the requirements of:*
>
> *(a) the publications issued by the Australian Accounting Research Foundation, on behalf of the Australian Society of Certified Practising Accountants and the Institute of Chartered Accountants in Australia, under the titles "Statements of Accounting Concepts" and "Australian Accounting Standards", as in force for the time being, subject to the regulations; and*
>
> *(b) such other standards as may be prescribed by the regulations*
>
> (LGA 1993 in White 1993)

At present these requirements state that councils in New South Wales should prepare financial reports in accordance with Australian Accounting Standard 27 (AAS27). One of the requirements of this standard is that reports should include a capitalisation of all infrastructure assets (Grant and Gordon, 1993). This means that councils must now maintain records and report on what assets they have and what their condition is.

Roorda (1995) points out that these assets will include such things as buildings, monuments, roads, bridges, underground pipes and drains, parks and reserves. Each of these assets have spatial attributes. Roorda goes on to show that technologies such as GIS can be used to effectively manage these assets and also be used to fulfil the requirements of AAS27.

Part 4 of Chapter 13 deals with annual reporting of councils. Section 428 sets out the information required to be included in each report. It includes such things as:

S.428(2) A report must contain the following particulars:

(c) a report as to the state of the environment in the area, including a report as to:

(i) areas of environmental sensitivity; and

(ii) important wildlife and habitat corridors; and

(iii) any unique landscape and vegetation; and

(iv) development proposals affecting, or likely to affect, community land or environmentally sensitive land; and

(v) polluted areas; and

(vi) any storage and disposal sites of toxic and hazardous chemicals; and

(vii) waste management policy; and

(viii) threatened species and any recovery plans; and

(ix) any environment restoration projects; and

(x) vegetation cover and any instruments or policies related to it, including any instruments relating to tree preservation;

(d) a report on the condition of the public works (including public buildings, public roads and water, sewerage and drainage works) under the control of the council as at the end of that year, together with:

(i) an estimate (at current values) of the amount of money required to bring the works up to a satisfactory standard; and

(ii) an estimate (at current values) of the annual expense of maintaining the works at that standard; and

(iii) the council's program of maintenance for that year in respect of the works;

.....

> (i) *details of programs undertaken by the council during that year to preserve, protect, restore and enhance the environment;*
>
> (i1) *a report on the bush fire hazard reduction activities of the council during that year, including activities carried out under a bush fire management plan approved under the Bush Fires Act 1949;*

.....

(LGA 1993 in White 1993)

As with other parts of the Act, many of the items required to be reported upon by Section 428 have a spatial nature. In this case however, the Act is somewhat more specific about the type of information that is to be collected. It is quite conceivable that councils will choose to use GIS technology to aid in the creation of annual reports.

Thus, it can be seen that the introduction of the *Local Government Act, 1993*, requires councils to collect and use a wide range of different spatial data types. This data is used by councils for performing its service responsibilities, managing its assets and creating annual reports. It can also be seen that, whilst the Act requires certain specific pieces of information to be collected, it gives councils a degree of freedom as to how certain responsibilities are to be fulfilled. This means that it is quite feasible that individual councils will use different data types for carrying out these responsibilities.

A.2 Other Important Legislation

The *Local Government Act, 1993*, is not the only piece of legislation affecting the responsibilities of local government in New South Wales. There are a number of other Acts which also define certain responsibilities for councils (White, 1993, p1171-1204). A number of these responsibilities may also require the use of spatial information. The following sections detail some of the more important pieces of legislation which may require councils to collect and the use spatial information.

A.2.1 Bush Fires Act, 1949

Councils are responsible for the management of fire hazard reduction work in their particular areas (Robertson 1993, p7092). Spatial information will be necessary for knowing where work has taken place as well as determining areas of high risk.

Councils also have the ability to determine the areas of operation of particular bush fire brigades (Robertson 1993, p 7151). Once again this will require the use of certain pieces of spatial information.

A.2.2 Coastal Protection Act, 1979

This Act imposes certain restrictions upon development in coastal areas. As local government is responsible for local development, it will be necessary for councils to be aware of those areas falling under the provisions of this Act (White, 1993, p1201).

A.2.3 Crown Lands Act, 1989

Under the *Crown Lands Act, 1989*, the Crown has the ability to vest Crown Land to councils. This land then becomes the responsibility of that particular council (Robertson 1993, p15187). Council will need to know where these particular parcels of land are.

A.2.4 Environmental Planning and Assessment Act, 1979

The *Environmental Planning and Assessment Act, 1979*, gives councils a number of very important responsibilities for which the use of spatial information is essential. These include, the creation of Local Environment Plans and Development Control Plans and the issuing of Section 149 Certificates.

Under this Act, councils are required to create Local Environment Plans (LEP). These plans are used to control development within a council's area and are based upon extensive environmental studies, existing land uses and the council's plans for the area. It can be seen that a great deal of spatial information will be necessary for the formulation of such plans. Furthermore, an important part of the process of creating such a plan is a period of public display. This display requires the creation of maps showing the areas affected by the proposed plan. The creation of these maps will require certain spatial information.

A Development Control Plan (DCP) is similar to an LEP, except that it covers a smaller area and allows council to be somewhat more specific with certain development regulations. Once again, spatial information is essential for the creation of these plans.

Section 149 of the Act allows land holders the right to obtain from councils a certificate indicating those planning controls existing over their land. Obviously, for councils to determine this information, it will be necessary to maintain certain spatial information about individual land parcels and properties within their area of control. Most importantly, it will be necessary for the council to have cadastral information so as to locate the property in question.

It can be seen that, in regard to the use of spatial information, this Act places a number of responsibilities upon local government. For a more detailed discussion of local government and the *Environmental Planning and Assessment Act, 1979*, see Whitmore 1981, Chapter 11.

A.2.5 Heritage Act, 1977

This Act allows for the placing of conservation orders and other development controls over items which are considered, by the Heritage Council of NSW, to be of some heritage value (White 1993, p1204). As councils are responsible for development in their area, it is necessary for them to know where these heritage items are.

A.2.6 Roads Act, 1993

Section 7(4) of the *Roads Act, 1993*, states that:

> *The council of a local government area is the roads authority for all public roads within the area, other than;*
>
> *(a) any freeway or Crown road; and*
>
> *(b) any public road for which some other public authority is declared by the regulations to be the roads authority.*
>
> (Roads Act, 1993, in Robertson 1993, p23242.)

It can be seen from Section 7(4) that councils are responsible for the creation, maintenance and regulation of many of the roads within their particular areas of control. In order to carry out these functions it is conceivable that a large amount of spatial information will be required. This information might include such data as road centrelines, road pavement areas and bridges.

A.3 Summary of Legislation

The previous sections have reviewed a few of the more important pieces of legislation which may require the use of spatial information by local governments in New South Wales. As a result, it can be seen that the data required to fulfil council's obligations under these acts will be quite varied in nature. Thus it is quite possible that councils will maintain spatial information relating to such things as cadastral boundaries, roads, assets, the environment, and utilities.

It can also be seen from this review that few of these acts actually require the collection of specific pieces of spatial information. Rather, the type of information used to fulfil the responsibilities imposed by these acts will be determined by individual councils. Thus, it is actually necessary to investigate individual councils to determine exactly what types of information they use and how they use it.

APPENDIX B: LOCAL GOVERNMENT SPATIAL DATA SETS

Following is a description of each of the 76 unique data sets identified from a survey of 36 local governments in New South Wales. It is not suggested that the data sets listed here form a comprehensive list of all spatial information used by councils in NSW. Nor is it suggested that different sets of unique data could not be identified from the same survey results. Rather, it is felt that this list is representative of the types of spatial data that a council might use.

In order to simplify the process of describing each data set, the list has been sorted into categories based upon the data type and use. Once again, it is not suggested that this categorisation method is perfect and it may be possible that a data set listed in one category here may also belong in another category.

Each data set is described as follows:

- A brief description of the data set and its uses is given;
- The feature types (points, lines, polygons) used within the data set are listed;
- The types of positional relationships (if any) existing between these features are listed; and
- Any other data sets containing features upon which the features in this set might be dependant are listed.

<table>
<tr><td colspan="3">Details:
Purpose for which the data is used and details on how the spatial information in the set is collected or created.</td></tr>
<tr><td>Feature Types:
Feature types used within the data set to represent real world features.</td><td>Related Data Sets:
Data sets containing features upon which features in this data set are dependant.</td><td>Relationship Types:
The types of relationships existing between these features</td></tr>
<tr><td colspan="3">References:
Any references used.</td></tr>
</table>

Airports

Airport Approaches

Details:
An airport approach is the path that an aeroplane takes as it approaches or leaves at particular runway. This path is represented by a cone emanating from the end of the runway and following the line of approach/departure.

It is necessary to ensure that airport approaches are free from all obstructions. These obstructions include buildings, communication towers and large trees. This data set is therefore used as a planning tool to ensure that potential developments do not impinge upon approaches.

With respect to the management of airports it is important to ensure that approaches do not overlap.

Feature Types:	Related Data Sets:	Relationship Types:
• Line • Polygon • Volume	• Runway Centrelines	• Point Coincidence • Model

References:

- **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, October-November, 1995.

Runway Centreline

Details:

Runway centrelines are usually mapped with respect to some mapping datum (eg. Australian Map Grid (AMG) or the NSW Integrated Survey Grid (ISG)). That is they are not generally related to features in other data sets other than survey control.

One of the more important purposes of this data set is a datum to which the runway approaches are related.

Feature Types:	Related Data Sets:	Relationship Types:
• Line	None	None

References:

- **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, October-November, 1995.

Tarmac & Taxiways

Details:

Tarmacs and taxiways are the pavements along which aeroplanes travel when on the ground. They are quite similar to roads and as such they must be maintained if damage to planes is to be avoided. Furthermore, if under council control, they are assets of the council and hence must be included in financial reports.

In order to determine the positions of tarmacs and taxiways, many methods can be used. The most obvious is to use offsets from runway centrelines, however many other measurement based relationships can be used. Furthermore it is possible that the data will be captured without using survey techniques at all. Rather it is created using positional relationships.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygon	• Runway Centrelines	• Offset + others • Relative Position

References:

• **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, October-November, 1995.

Asset Management

Council Managed Land

Details:		
Councils own and/or manage many parcels of land within their areas of control. These parcels can be divided into 3 categories; operational, community and crown lands. Operational lands are used by council in order to carry out its functions. Thus council buildings, depots and treatment works are generally on operational land. Community lands include such places as public parks and sporting fields. Crown land is not owned by council, however, in many cases these lands are managed by local councils. It can be seen that the uses to which operational, community and crown lands might be put are many and varied. In order for a council to manage these parcels it is necessary to know, amongst other things, where each parcel is and what it is used for. In general the boundaries of these parcels of land will be coincident with cadastral boundaries.		
Feature Types: • Polygon	**Related Data Sets:** • Cadastre (present)	**Relationship Types:** • Line Coincidence
References: • **Milby G., 1995,** Personal Communication with Mr Gary Milby, Canterbury City Council, June, 1995.		

Park Furniture

<table>
<tr><td colspan="3">Details:
Includes assets such as: Park Benches, Garbage Bins, Trees, Playground Equipment, etc.

With the increasing emphasis on the need for councils to capitalise their assets and hence manage them properly, a number of councils are collecting spatial information about these assets.

A councils basic requirement for the positions of this asset data is to know where an asset is with respect to the surrounding environment. In the case of a park, this environment will probably be the cadastre.</td></tr>
<tr><td>Feature Types:
• Points</td><td>Related Data Sets:
• Cadastre (present)</td><td>Relationship Types:
• Many measured relationships. eg. Bearing/Distances, Offsets, etc.
• Relative Position</td></tr>
<tr><td colspan="3">References:</td></tr>
</table>

Street Furniture

Details:		
Includes assets such as Footpaths, Kerb and Guttering, Median Strips, Sign Posts, etc. Similar to Park Furniture except that some of these assets will be represented by polygons as well as point features. Furthermore individual councils may actually choose to relate these features to those other than the cadastre. These other features include road centrelines, or in some cases, survey control.		
Feature Types: • Points • Polygons	**Related Data sets:** • Road Centreline • Cadastre (present) • Survey Control	**Relationship Types:** • Many measured relationships. eg. Bearing/Distances, Offsets, etc. • Relative Position
References:		

Other Assets

Details:

Includes assets such as: council owned buildings, depots, etc.

The data set includes those assets not covered by Park Furniture, Street Furniture, and the Utility and Transport data sets. In general this will cover structures such as buildings (councils chambers, depots, etc.).

As for the other asset types, councils are in need of a relative position between these assets and some other feature (usually the cadastre).

Feature Types:	Related Data Sets:	Relationship Types:
• Points (possibly) • Polygons	• Cadastre (present)	• Many measured relationships. eg. Bearing/Distances, Offsets, etc. • Relative Position

References:

Administrative Boundaries

Agricultural Land Classification

Details:

The Department of Agriculture and Fisheries is responsible for deciding what types of agriculture are suitable for specific pieces of land. This is done by classifying the land with respect to certain environmental factors such as; local climate, soil conditions, slopes as well as nearby land uses. The Department then creates an Agricultural Classification Map for the area.

Local Governments are large users of Agricultural Land Classifications information as it is used to control certain agricultural developments. However, whilst classifications are based upon certain environmental factors, the classification is very much in control of the Department. Councils must use Department classifications.

This data set is sometimes referred to as a Land Capability data set.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	None	None

References:

- **Fuller D., 1995,** Personal Communication with Mr David Fuller, NSW Department of Agriculture and Fisheries, November, 1995.
- **Wilson J., 1995,** Personal Communication with Mr. John Wilson, NSW Department of Agriculture and Fisheries, November, 1995.
- **Hanlon G., 1997,** Personal Communication with Mr. Gavin Hanlon, Environmental Scientist, Liverpool City Council, March, 1997.

Building Lines

Details:

Section 308 of the *Environmental Planning and Assessment Act, 1979* gives councils the ability to define and enforce building lines. These are lines which run parallel to a parcel boundary such that construction between this line and the parcel boundary is not permitted. Thus they are used as a form of development control by councils.

Strictly speaking the Act states that construction may not take place between the building line and any public place or reserve. Thus, as a road is a public place, these lines are generally used as a set back from roads.

Feature Types:	Related Data Sets:	Relationship Types:
• Lines	• Cadastre (present)	• Offset

References:

- **Whitmore H., 1981,** Local Government and Environment Planning Law (in New South Wales), The Law Book Company, Sydney, 169pp.

Cadastre (future)

Details:

Councils are responsible for managing development within their areas of control. Such developments may include changes to the cadastre. A number of councils, in order to manage developments and save time, capture proposed cadastral changes as a separate data set. This data can then be used to update the cadastre once any changes have been registered by council and the Land Titles Office (LTO).

Such a data set is obviously very closely associated to the present cadastre.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present)	• Line Coincidence • Point Coincidence • Distance along line

References:

Cadastre (past)

Details:

There are many reasons for maintaining historical cadastral information. It is useful for monitoring the rate of development in specific areas and as a reference for determining land use at particular times in history. However the features in a number of data sets are related specifically to the cadastre at the time they were created. Thus, if these relationships are to be managed correctly, information about the cadastre at the time the relationship was created should be kept.

If a council does maintain historical information, it is likely that it actually consist of a number of separate data sets, each representing the cadastre at a different point in time.

In terms of the creation of historical data sets there will be no specific positional relationships used other than those used to create the data set when it was the present cadastre. In general this means that there will be no positional relationships involved.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	None	None

References:

Cadastre (present)

<table>
<tr><td colspan="3">Details:
The cadastre is one of, if not, the most important data sets used by councils. However, determining what relationships, if any, such a data set has is quite difficult. This is because cadastral boundaries in reality are related to natural features (the seashore, streams, lakes, etc.) or artificial features (monuments, fences, walls, etc.), some of which are not mapped by councils.

However, whilst these relationships exist, due to the importance of this data set, councils tend to relate features in other data sets to features in this set rather than vice versa.</td></tr>
<tr><td>Feature Types:
• Polygons</td><td>Related Data Sets:
None</td><td>Relationship Types:
None</td></tr>
<tr><td colspan="3">References:
• Willis R., 1982, Notes on Survey Investigation, Land Titles Office, NSW Dept. of Lands, 106pp.</td></tr>
</table>

Census Collection Districts

Details:

A Census Collection District (CCD) is the smallest division of land used by the Australian Bureau of Statistics (ABS) for reporting census information. A CCD is designed such that it is easy for a census collector to service, both in area and recognition of boundaries.

Councils are a large user of census information and hence CCDs are designed to be coincident with local government boundaries. An effort is also made to use Electorate and Ward boundaries where possible. Otherwise any recognisable feature may be used to define a CCD.

In order to allow for easy comparisons between surveys, the ABS avoids changing CCD boundaries where possible.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Electorates • Wards • Local Government Areas • Road Centrelines • Rail Centrelines • Natural Drainage	• Line Coincidence

References:

- **Ramsey G., 1995,** Personal Communication with Mr Geoff Ramsey, Australian Bureau of Statistics, August, 1995.

County Boundaries

Details:

The State of NSW is divided into 141 counties. These counties date back to the original land grants system used to control expansion of the colony (eg. the famous 19 counties outside which development was forbidden). Of these 141 counties only 35 were ever 'proclaimed'. The remainder were simply gazetted at some later date. The definition of a county boundary hence can be somewhat vague, as a 'metes and bounds' type description was not always provided. In order to overcome this problem, it is possible to relate County Boundaries to Parish Boundaries, as each county is divided into a series of parishes.

The use a Council might have for this data set is somewhat unclear, except for that fact that certain other data sets may actually be related to County Boundaries (eg. Electorates, Census Collection Districts, and some regional management plans).

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Parish Boundaries	• Line Coincidence

References:

- **Hallman F., 1973,** Legal Aspects of Boundary Surveying as apply in New South Wales, (Institution of Surveyors, Australia (NSW), 283pp.
- **Lands Dept., 1947,** The Parish Map - Training Paper 6, Lands Office Training Manual.
- **King C., 1957,** An Outline of Closer Settlement in New South Wales, NSW Department of Agriculture, p39.

Development Control Plans

Details:

Section 72 of the *Environmental Planning and Assessment Act, 1979* gives councils the ability to create Development Control Plans (DCP). These plans are very similar to Local Environment Plans (LEP) except for the fact that they cover much smaller areas and are not controlled to the extent of LEPs. Their purpose is to regulate development in specific areas where more control than that provided by the LEP is required.

It can be seen that a DCP will be very closely related to an LEP. Thus the boundaries of areas controlled by them are determined with respect to many features, but usually related specifically to the cadastre and LEP boundaries.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present) • Cadastre (past) • Local Environment Plans - General Provisions • Local Environment Plans - Zoning	• Line Coincidence • Bearing/Distance • Offset • Point Coincidence • Others

References:

- **Gronlund M., 1995,** Personal Communication with Mr Michael Gronlund, Blue Mountains City Council, September, 1995.
- **Graham R., 1995,** Personal Communication with Mr Ron Graham, Coffs Harbour City Council, September, 1995.
- **McLeod A., 1991,** Lecture Notes from Subject: Land Subdivision and Development, School of Surveying, The University of New South Wales, 1991.

Easements

Details:

In general an easement is created to give one party (the dominant tenement) the right to use another party's (the serviant tenement) land for a specific purpose. These purposes include: the right to drain water, the right to transmit electricity, a right of carriageway, etc.

There are two cases for positional relationships with easements. Firstly, if the easement is created over an existing feature (pipe, tunnel etc.) then the position of the easement will be dependant upon the position of that pipe, tunnel etc. In all other cases the easement is to be created with respect to the cadastre.

In general the information supplied when an easement is created with respect to the cadastre is the position of the intersection of the easement with cadastral boundaries.

Feature Types:	**Related Data Sets:**	**Relationship Types:**
• Polygons	• Cadastre (present) • many others	• Bearing/Distance • Offset • Intersections

References:

- **Survey Practice Regulations, 1990,** New South Wales Government Gazette, 29 June, 1990, p5860-5880.

Electorates

Details:

There are three levels at which elections take place in Australia. They are; Federal, State and Local Government. Local Government electorates are defined by Local Government and Ward boundaries which have been defined elsewhere.

The process of dividing the state and nation into electorates is performed by the appropriate electoral commission. These commissions endeavour to create electorates of roughly the same size based upon a set of well defined criteria. Boundaries are determined by allowing for such things as communication routes, natural boundaries and local community interests.

On the federal level a 'redistribution' must occur in each state at least every 7 years. Thus, electoral boundaries themselves, can be quite dynamic.

In general each commission defines electoral boundaries with respect to anything practical. Thus rives, lakes, parish boundaries, mountain ranges, roads and many other features are used.

Continued on next page...

Feature Types:	Related Data sets:	Relationship Types:
• Polygons	• Cadastre (present) • Parish Boundaries • Local Government Areas • Census Collection Districts • National Park/State Forest Bdys • Electricity Transmission Lines • Natural Drainage • Natural Water Features • Rail Centrelines • Road Centrelines • Road Corridor Centrelines • Ridge Lines	• Line Coincidence

References:

- **AEC 1987,** Redistribution of Electoral Districts, Electoral District Commissioners Report, Australian Electoral Commission, 1987.
- **AEC 1992,** Report of Redistribution, Australian Electoral Commission, 1992.
- **AEC 1994a**, Electoral Newsfile No 38, Australian Electoral Commission, 1994.
- **AEC 1994b**, Electoral Newsfile No 40, Australian Electoral Commission, 1994.

Fire Brigade Districts

Details:

The *Bush Fires Act, 1949*, gives councils the ability to determine the area of operations of Bush Fire Brigades. These brigades are then responsible for the management of bush fires in these particular areas.

In order to define a brigade area, councils use easily recognised features such as natural boundaries and road centrelines to designate boundaries.

Feature Types:	**Related Data Sets:**	**Relationship Types:**
• Polygons	• Cadastre (present) • Road Centrelines • Rail Centrelines • Natural Drainage • Natural Water Features • National Park/State Forest Boundaries • Ridgelines	• Line Coincidence

References:

- **Murray D., 1995,** Personal Communication with Ms. Diane Murray, Port Stephens Council, October, 1995.
- *Local Government Act, 1993*: in **White S., 1993,** Local Government Law and Practice: New South Wales, Volume 1, The Law Book Company, Sydney.
- *Bush Fires Act, 1949*: in **Robertson S., 1993,** Local Government Law and Practice: New South Wales, Volumes 2 and 3, The Law Book Company, Sydney.
- *Fire Brigades Act, 1989*: in **Robertson S., 1993,** Local Government Law and Practice: New South Wales, Volumes 2 and 3, The Law Book Company, Sydney.

Leases

Details:

In some instances, councils will lease buildings, rooms in buildings, areas in parks, etc. to private organisations for the running of kiosks, day care centres etc. In some cases, the rent paid for these leases will be based upon the area of the room or building being let. Therefore this area is important to both the lessee and council (the lessor).

Some councils have started to collect information about the location of these leased areas. In general they are surveyed and related directly to the present cadastre.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present)	• Bearing/Distance • Line Coincidence

References:

- **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, November, 1995.

Local Aboriginal Land Councils Districts

Details:

The area of an Aboriginal Land Council is compiled by the NSW Land Information Centre (LIC) through consultation with local aborigines. Of the councils surveyed, none used this data set, however it is quite possible that councils may need to have knowledge of these areas. This is especially the case with continuing dispute over such things as Native Land Title.

The compilation of the boundaries of these areas was originally performed with respect to the cadastre. These boundaries, therefore, remain coincident with the cadastre at the time the boundary is gazetted.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (past)	• Line Coincidence

References:

- **Fitzmorris A. 1995,** Personal Communication with Mr Allan Fitzmorris, Land Information Centre, NSW Department of Conservation and Land Management, October, 1995.

Local Environment Plans - General Provisions

Details:

This data set forms part of a council's Local Environment Plan and in fact is used as a type of secondary zoning plan. The information relates to areas of environmental concern within the particular local government area. Developers whose proposed developments fall within these areas are required to demonstrate how their development will affect the local environment. In particular this data set is designed to ensure that development does not have an adverse effect upon features of particular environmental significance.

The data in these maps is created using environmental information such as vegetation types and the habitats of various threatened species. However, as for Zoning plans, once an area has been defined by a particular council and gazetted, these boundaries remain related to the cadastre at the time of gazettal until changed by a new gazettal.

Feature Types:	**Related Data Sets:**	**Relationship Types:**
• Polygons	• Cadastre (past)	• Line Coincidence • Bearing/Distance • Offset • Point Coincidence • Others

References:

- **Gronlund M., 1995,** Personal Communication with Mr Michael Gronlund, Blue Mountains City Council, September, 1995.
- **Hanlon G., 1997,** Personal Communication with Mr. Gavin Hanlon, Environmental Scientist, Liverpool City Council, March, 1997.

Local Environment Plans - Zoning

Details:

Local Environment Plans (LEPs) are documents by which a council plans for development within its area. A major part of these plans are zones which prescribe the type of development that council will permit in a particular area.

The various zoning boundaries can be determined with respect to many different features (eg. tree lines, lines of sight, contour lines, cadastral boundaries, natural boundaries). However, once a particular LEP has been gazetted, these boundaries remain related to the cadastre at the time of gazettal.

The relationship between LEP zones and the cadastre is recognised as being very important for local government.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (past)	• Line Coincidence • Bearing/Distance • Offset • Point Coincidence • Others

References:

- **Smith J., 1995,** Personal Communication with Ms. Judy Smith, Hastings Council, April, 1995.
- **Whitmore H., 1981,** Local Government and Environment Planning Law (in New South Wales), The Law Book Company, Sydney, 169pp.

Local Government Area

Details:

The boundaries of a council's area of operation is obviously very important to that council. They are usually defined with respect to natural features such as roads, streams, ridges etc as well as the cadastre.

In general the boundaries are described by a 'metes and bounds' description gazetted by the Local Government Boundaries Commission. The role of the Commission is to determine where the boundaries of a particular community are. This community will then form the basis for the local government.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present) • Road Corridor Centrelines • Natural Water Features • Contours	• Line Coincidence

References:

- *Local Government Act, 1993*: in **White S., 1993,** Local Government Law and Practice: New South Wales, Volume 1, The Law Book Company, Sydney.
- **Fitzmorris A. 1995,** Personal Communication with Mr Allan Fitzmorris, Land Information Centre, NSW Department of Conservation and Land Management, October, 1995.

Mine Subsidence Districts

Details:

In some areas of the State, mining has, and is taking place under the ground. In these areas, the Mine Subsidence Board has certain responsibilities. One of the Board's responsibilities is to define those areas which fall under its authority. That is, those areas deemed susceptible to subsidence as a result of mining.

The classification of these areas is done by a 'metes and bounds' description. Susceptible Areas are related to Parish or cadastral (past and present) boundaries.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present) • Cadastre (past) • Parish Bdys	• Line Coincidence

References:

- **Connelly P., 1995,** Personal Communication with Mr. Peter Connelly, NSW Mine Subsidence Board, November, 1995.

Multiple Assessments

Details:

According to one particular council, in certain circumstances the Valuer General may give more than one assessment number to a particular property. In such cases, the local council may wish to give the property more than one rating assessment. Thus, this data set consists of those parcels of land which fall into this category.

As with all rateable properties, the polygons in this data set are completely coincident with the present cadastre.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present)	• Line Coincident

References:

- **Zouain S., 1995,** Personal Communication with Ms. Suzy Zouain, Canterbury City Council, September, 1995.

National Park/State Forest Boundaries

Details:

Generally, National Park and State Forest Areas are areas which are outside the control of local government. In the case of National Parks, they are usually areas which have some environmental significance. For these reasons it is important for councils to know where they are.

The boundary of a National Park will be coincident with some cadastral boundary. State Forests however, may not necessarily be coincident with the cadastre. This especially the case where the forest is on Crown Land. In these cases a 'metes and bounds' description is used to define the area.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present)	• Line Coincidence

References:

- **Harris K., 1995,** Personal Communication with Mr. Kevin Harris, Cartographer, NSW National Parks and Wildlife Service, August 1995.
- **Rubic N., 1995,** Personal Communication with Mr. N Rubic, State Forests, August, 1995.

Parcels

Details: A land parcel data set is in reality a subset of the cadastre. Basically it is the cadastre with only those polygons which are contiguous parcels of land. It does not include separate parcels in a road or rail corridor. The only line features within the data set are cadastral boundaries. The reason many councils use a parcel data set is that the Land Information Centre's Digital Cadastral Data Base (DCDB), includes a great number of line features which are not cadastral boundaries. These features are used to identify road intersections and the location of a number of other administrative boundaries (eg. Suburb Boundaries). Many councils wish to have a cadastral data set which is free of these extra features.		
Feature Types: • Polygons	**Related Data Sets:** • Cadastre (present)	**Relationship Types:** • Line Coincidence
References:		

Parish Boundaries

Details:

Historically, the parish is the original cadastre in NSW. The state was divided into counties which were further divided into parishes. These in turn were divided into Portions. Land was then granted with respect to these portions.

This system originated in England where the size of a parish was based upon the area a Parish Priest could cover in one day. This measure was not used in NSW. However each parish is roughly the same size.

Despite, the fact that the County/Parish/Portion system has been superseded by the Lot/Deposited Plan, there are a number of instances where Parish Boundaries are still used. These cases generally occur when other data sets are related to these boundaries (eg. Electorates, Suburb Boundaries).

Unfortunately, due to the history of Parish Boundaries, they are not, themselves, related to anything. That is, the position of a Parish Boundary is not dependant upon the position of other features.

Feature Types:	Related Data Sets:	Relationship Types:
Polygons	None	None

References:

- **Hallman F., 1973,** Legal Aspects of Boundary Surveying as apply in New South Wales, (Institution of Surveyors, Australia (NSW), 283pp.
- **Fitzmorris A. 1995,** Personal Communication with Mr Allan Fitzmorris, Land Information Centre, NSW Department of Conservation and Land Management, October, 1995.

Postcode Areas

Details:

Postcode boundaries are the realm of Australia Post and the Australian Land Information Group (AUSLIG). They are used by Australia Post to aid in the sorting and delivering of mail. They are not surveyed. Rather, like a number of other boundaries, they are designed by following any practical and recognisable boundary.

It is not clear what purpose a council would have for such a data set, however at least one council suggested that they were going to collect this information.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present) • Road Centrelines • Rail Centrelines • Streams • Ridges	• Line Coincidence

References:

- **APC, 1992,** Postcode Boundary Users Guide 1992, Australian Postal Corporation, 1st Edition, p12-17.
- **Virtue I., 1995,** Personal Communication with Mr. Ian Virtue, Australian Land Information Group (AUSLIG), November, 1995.

Precinct/Neighbourhood Areas

Details:

A number of councils divide their area of control into precincts or neighbourhoods. These are areas which the council has deemed to have some community spirit. Council then allows local interest groups to have some input into the affairs of that area.

In general these areas are defined using coincidence to cadastral and or suburb boundaries.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present) • Suburb Boundaries	• Line Coincidence

References:

- **Murray D., 1995,** Personal Communication with Ms. Diane Murray, Port Stephens Council, October, 1995.

Proclaimed Survey Areas

Details:

A Proclaimed Survey Area (PSA) is an area in which cadastral surveyors are required, through legislation, to connect cadastral surveys to State Survey Control points. These points are registered by the state government and allow for these surveys to be coordinated upon a common datum.

Of the councils surveyed, none actually used this data set, however it is a product of the Land information Centre (Dept of Land and Water Conservation), hence has relationships to other LIC products such as the Digital Cadastral DataBase (DCDB) used by many councils.

At present (1995), the boundaries of Proclaimed Survey Areas were based upon the LIC's 1:10000 map sheet series. However, it is intended that this system will be changed and future PSAs will be related directly to Suburb/Locality boundaries.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Suburb/Locality	• Line Coincidence

References:

- **Fitzmorris A. 1995,** Personal Communication with Mr Allan Fitzmorris, Land Information Centre, NSW Department of Conservation and Land Management, October, 1995.

Properties - Rateable

Details:

A property, whilst being directly related to the cadastre, is not a land parcel. Rather it is a piece of land (possibly many parcels) which is regarded by council as being contiguous. In general, this means that one person or organisation owns and uses that piece of land as a whole.

Properties, and in particular rateable properties, form the basis for the charging of rates by councils.

The *Local Government Act, 1993* gives councils the ability to charge rates on certain properties within their area.

Feature Types:	Related Data sets:	Relationship Types:
• Polygons	• Cadastre (present)	• Line Coincidence

References:

- **White S., 1993,** Local Government Law and Practice: New South Wales, Volume 1, The Law Book Company, Sydney.
- **Gronlund M., 1995,** Personal Communication with Mr Michael Gronlund, Blue Mountains City Council, September, 1995.

Properties - Other

Details: This data set is exactly the same as the Rateable Properties data set, except that it includes non rateable properties (eg. Railway lands, National Parks, Schools, etc.) These two data sets could probably be included as one.		
Feature Types: • Polygons	**Related Data Sets:** • Cadastre (present)	**Relationship Types:** • Line Coincidence
References:		

Regional Environment Plans

Details:

A Regional Environment Plan (REP) is created by the NSW Department of Planning, and is used to manage some aspect of the environment within a particular area, or region.

Unfortunately the method by which an REP spatial data set is created is very much dependant upon the purpose for the REP. Thus, if the REP deals with a particular river system, the boundaries of the REP may be the water catchment. In cases of a plan dealing with a particular town centre, however, the region may be defined using cadastral boundaries.

Feature Types:	**Related Data Sets:**	**Relationship Types:**
• Polygons	• Cadastre (present) • Cadastre (past) • Many others.	• Line Coincidence • Bearing/Distance • Offset • Point Coincidence • Other

References:

- **Shortis S., 1995,** Personal Communication with Mr. Stephen Shortis, NSW Department of Planning, September, 1995.

Road and Rail Corridors

<table>
<tr><td colspan="3">Details:
Once again, this is another data set which is closely related to the cadastre. In this case, the data set consists of only those parcels which form part of the road or rail corridor. In the case of road corridors, this data set might be used in conjunction with a Pavement Management System (PMS).
The boundaries of these corridors are coincident with the cadastre.</td></tr>
<tr><td>Feature Types:
• Polygons</td><td>Related Data Sets:
• Cadastre (present)</td><td>Relationship Types:
• Line Coincidence</td></tr>
<tr><td colspan="3">References:
• Batley K., 1997, Personal Communication with Mr Kim Batley, GIS Coordinator, Liverpool City Council, March, 1997.</td></tr>
</table>

Rural Lands Protection Districts

Details:

This data set is yet another which is produced by the Land Information Centre (LIC) but not used by any of the councils surveyed. It shows the boundaries of each of the Rural Lands Protection Districts (formerly Pasture Protection Board Districts) in New South Wales.

The boundaries of these districts are coincident with the cadastre, however there are moves to relate them to Local Government Areas.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present) • Local Government Areas	• Line Coincidence

References:

- **Fitzmorris A. 1995,** Personal Communication with Mr Allan Fitzmorris, Land Information Centre, NSW Department of Conservation and Land Management, October, 1995.

Sect. 94 EP&A Act

Details:

Section 94 of the *Environment Planning and Assessment Act, 1979*, gives councils the ability to charge a contribution from developers for such things as the construction of roads, development of public parks, etc. Some councils may charge a flat rate across the entire council area for this contribution. Others, however, may vary the contribution depending upon the area of the development.

This data set consists of the boundaries between areas where the s.94 contribution levels change. In general it is related directly to the present cadastre.

Feature Types:	**Related Data Sets:**	**Relationship Types:**
• Polygons	• Cadastre (present)	• Line Coincidence

References:

- **McLeod A., 1991,** Lecture Notes from Subject: Land Subdivision and Development, School of Surveying, The University of New South Wales, 1991.
- **Graham R., 1995,** Personal Communication with Mr Ron Graham, Coffs Harbour City Council, September, 1995.

State Border

Details:

Obviously only those councils which have part of their boundary as the state border will collect this data set. For these council, however, there are a number of data sets which may be related to this one (eg. Electorates, Parish Bdys, etc)

The cadastre is also closely related to the state border as theoretically the cadastral framework cannot exist outside the state. However, as with a number of other data sets and due to the importance of the cadastre, it is probably more appropriate to relate the state border to the cadastre.

Feature Types:	Related Data sets:	Relationship Types:
• Line	• Cadastre (present)	• Line Coincidence

References:

Suburb/Locality Boundaries

Details:

Suburb Boundaries are defined by the NSW Geographical Names Board and are used for a number of purposes. One of these is as the basis for giving addresses to rural properties.

Councils have some input into the positioning of suburb boundaries and also have a number of uses for them.

They are a subdivision of a local government area and, similar to local government areas, are defined as being coincident with features in number of other data sets.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present) • Road Corridor • Natural Drainage • Contours • Local Government Bdys	• Line Coincidence • Other

References:

- **Gronlund M., 1995,** Personal Communication with Mr Michael Gronlund, Blue Mountains City Council, September, 1995.
- **Murray D., 1995,** Personal Communication with Ms. Diane Murray, Port Stephens Council, October, 1995.
- **Fitzmorris A. 1995,** Personal Communication with Mr Allan Fitzmorris, Land Information Centre, NSW Department of Conservation and Land Management, October, 1995.

Town Area

Details: This data set is simply a representation of what council has decided is a Central Business District within their area. It is quite similar to a Precinct data set and should be included within that data set.		
Feature Types: • Polygons	**Related Data Sets:** • Cadastre (present)	**Relationship Types:** • Line Coincidence
References: • **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, November, 1995.		

Wards

Details:

A ward is a subdivision of a Local Government Area used for electoral purposes.

The creation of ward boundaries is controlled by the *Local Government Act 1993*. Section 211 of the Act requires councils to consult with the Australian Electoral Commission (AEC) and the Australian Bureau of Statistic (ABS) to 'ensure that, as far as practicable, the proposed boundaries ... correspond to the boundaries of [electoral divisions] and census districts.'

Thus it can be seen that these boundaries are designed such that they are coincident with electoral boundaries, census collection district boundaries and, obviously, the local government area boundary.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Electorates • Census Collection Districts • Local Government Area	• Line Coincidence

References:

- **White S., 1993,** Local Government Law and Practice: New South Wales, Volume 1, The Law Book Company, Sydney.

Environmental Data

Endangered Fauna and Flora

Details:

Includes such data as: areas of Littoral Rainforest, areas of Koala populations, etc.

Due to an increasing need for environmental awareness, through both legislative requirements and public demand, councils are finding it necessary to know where particular species of plant and animal exist in their area. It is then possible to control development in these areas and protect these species.

Many councils are creating maps of this data with respect to the cadastre, zoning boundaries, and other useful boundaries. These maps consist of polygons around the areas of these plants and animals.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present)	• Line Coincidence

References:

- **Murray D., 1995,** Personal Communication with Ms. Diane Murray, Port Stephens Council, October, 1995.

Land Slip Areas

Details:

Knowledge of areas of potential land slips is essential for determining the viability of certain land developments. Thus there is a great need for councils to have this information.

This data set is very much dependant upon other environmental data sets such as soil types and slopes. It is calculated using various mathematical models.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Soil Types • Slopes	• Model

References:

Natural Drainage

Details:

Natural drainage is an environmental data set and as such the features within it are not generally related to features in any other data sets. It represents such things as the centrelines of creeks and rivers.

In some cases the cadastre may actually be related to features in this data set. However, due to the importance of the cadastre and the potential accuracy differences between it (more accurate) and this data set, it seems somewhat foolish to relate the cadastre to natural drainage features. It is, however, possible to relate these natural drainage features back to the cadastre. This is done using line coincidence and bearing and distance type relationships.

Feature Types:	Related Data Sets:	Relationship Types:
• Lines	None or • Cadastre (present) • Cadastre (past)	None or • Line Coincidence • Bearing/Distance

References:

- **Hallman F., 1973,** Legal Aspects of Boundary Surveying as apply in New South Wales, (Institution of Surveyors, Australia (NSW)), 283pp.

Natural Water Features

Details:		
This data set is very similar to the Natural Drainage data set except that the features (eg. lakes, seas, dams, large rivers) are represented by polygons rather than lines. Once again cadastral features may actually be related to features in the data set but it would be unwise to enforce these relationships.		
Feature Types:	**Related Data Sets:**	**Relationship Types:**
• Polygons	None or • Cadastre (present) • Cadastre (past)	None or • Bearing and Distance • Line Coincidence
References: • **Hallman F., 1973,** Legal Aspects of Boundary Surveying as apply in New South Wales, (Institution of Surveyors, Australia (NSW)), 283pp.		

Slopes

Details:

Information about the slope of land is used extensively for development planning. It is also used for engineering functions such as determining water runoff rates which are, in turn, used for calculating the requirements for stormwater drainage. Slope information can also be used as part of models to determine flood lines.

Slope information is derived directly from a Digital Elevation Model (DEM) which may in turn have been created from contour or some other height information source. That is, it is determined using a complex mathematical model.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Contours • Spot Heights • Other	• Other

References:

- **Burrough P., 1993**, Notes from Workshop given on 'Environmental Assessment and GIS.' School of Surveying, The University of New South Wales, Sydney, Australia, June, 1993.

Soil Landscapes

Details:

Mapping of soil types is not generally carried out by local government authorities in NSW. Rather the Soil Conservation Service is responsible for the creation of soil maps. In general the information is mapped at a scale of 1:100000 or 1:250000 with respect to a topographical map supplied from the Land Information Centre (LIC).

The information in this data set is not generally related to features in any other data sets.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	None	None

References:

- **Murray S., 1995,** Personal Communication with Mr Stuart Murray, GIS Unit, Soil Conservation Service, NSW Department of Lands and Water Conservation, November, 1995.

Vegetation

Details:

Vegetation information is stored by a number of councils. In general it is derived from satellite imagery and either consists of different land cover types (eg. forest, grassland, etc.) or divides the area in vegetation communities.

The use to which this information is put is varied. It is used in the creation of various development plans (see Local Environment Plans - General Provisions) and can be used in the creation of the various environmental; reports required of councils.

Unlike the Soil Landscapes data set, the information within this data set is quite often captured by council staff. As mentioned previously it can be captured from satellite imagery and then closely related to zoning boundaries, cadastral boundaries and the like. However, like many other environmental data sets it is not specifically related to any other data.

Feature Types:	Related Data sets:	Relationship Types:
• Polygons	None	None

References:

• **Hanlon G., 1997,** Personal Communication with Mr. Gavin Hanlon, Environmental Scientist, Liverpool City Council, March, 1997.

Water Catchment Areas

Details:

A water catchment area is generally the area surrounding a water feature such that all rain water falling in that area will find its way to that water body. A number of legal water catchment areas exist, For example the Lake Burrendong Catchment Area in the Blue Mountains of NSW. However, in general, the water catchment areas of interest to councils are natural boundaries.

Obviously the positions of features in a Water Catchment Area data set are very much dependant upon other natural features such as the positions of ridges, rivers and streams.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Natural Drainage • Contours • Ridges	• Line Coincidence • Other

References:

- **Fitzmorris A. 1995,** Personal Communication with Mr Allan Fitzmorris, Land Information Centre, NSW Department of Conservation and Land Management, October, 1995.
- **Leggatt G., 1995,** Personal Communication with Mr Geoff Leggatt, Hornsby Shire Council, October, 1995.
- **Graham R., 1995,** Personal Communication with Mr Ron Graham, Coffs Harbour City Council, September, 1995.

Environmental Hazards

Evacuation Sites

Details:

In certain parts of the state, the possibility of some disaster occurring is such that some councils have found the need to map the locations of evacuation sites for particular communities. This is especially the case, for example, for communities situated downstream from large water storage dams.

In general this information is represented with respect to the cadastre. This is done by either selecting the entire parcel and using this polygon to represent the site or by using a simple point.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons or • Points	• Cadastre (present)	• Line Coincidence or • Relative Position

References:

- **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, November, 1995.

Fire - Bushfire Data

Details:

The prevention of bushfires is an important role for many councils. Bushfires cause many thousands of dollars in damage each year. Resources for controlling bushfires are not great and hence it is in the interest of councils use them wisely.

One method for allocating these resources is to determine those areas which pose the greatest fire potential as well as to record those areas which have been affected by fire in the past.

This particular data set consists of polygons representing those areas which have been affected by either bushfires or controlled burning. These polygons are usually created with respect to the cadastre.

Feature Types:	Related Data sets:	Relationship Types:
• Polygons	• Cadastre (present)	• Line Coincidence

References:

- **Leggatt G., 1995,** Personal Communication with Mr Geoff Leggatt, Hornsby Shire Council, October 1995.
- **Murray D., 1995,** Personal Communication with Ms. Diane Murray, Port Stephens Council, October, 1995.

Fire - Hazard Areas

<table>
<tr><td colspan="3">Details:
Closely associated with the Bushfire Data Set is a data set showing areas of bushfire potential. This data set is quite similar to Bushfire Data, however in this case the information is calculated using models based upon many other pieces of data such as slopes, prevailing winds, vegetation, land use, etc.</td></tr>
<tr><td>Feature Types:
• Polygons</td><td>Related Data Sets:
• Slopes
• Vegetation
• Land Use
• Bushfire Data</td><td>Relationship Types:
• Model</td></tr>
<tr><td colspan="3">References:</td></tr>
</table>

Flood Lines/Zones

<table>
<tr><td colspan="3">Details:
Knowledge of what areas will be affected during particular flood events is quite important to councils. Not only is this information used to determine where to place particular pieces of infrastructure (buildings, pumps etc.) and where to allow particular types of development, it is also necessary to be able to determine where affected lands are during a flood (for emergency services etc.).

Whilst the relationship of flood lines to the cadastre is quite important. These two data sets are not actually related. Rather, flood lines are determined from models using contour information and water flows along lines of natural drainage.</td></tr>
<tr><td>Feature Types:
• Polygons</td><td>Related Data Sets:
• Contours
• Natural Drainage</td><td>Relationship Types:
• Other</td></tr>
<tr><td colspan="3">References:</td></tr>
</table>

Other Hazard Areas

Details:

Apart from Bushfires and Floods, there are a number of other possible sources of environmental hazards in which councils might be interested. These areas can include such things as the sites of present and past factories and service stations as well as the sites of former waste dumps and other contaminated sites. This information is used for planning purposes and, in some cases, may be used for emergency services purposes.

In general, these data sets are compiled by state organisations (eg. The NSW Workcover Authority) with respect to the cadastre and are represented by either simple points or by polygons.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons • Points	• Cadastre (present)	• Line Coincidence • Relative Position

References:

- **Milby G., 1995,** Personal Communication with Mr Gary Milby, Canterbury City Council, June, 1995.
- **Hanlon G., 1997,** Personal Communication with Mr. Gavin Hanlon, Environmental Scientist, Liverpool City Council, March, 1997.

Transport

Bridges

Details:

As a result of councils being responsible for certain roads within their area, they are also responsible for bridges on these roads. For some functions of local government, a number of councils have decided it is useful to have spatial information for bridges.

Obviously a bridge is very closely related to the route centreline (road, cycleway, railway, footpath, etc.) that the bridge conveys. Thus part of the position of the bridge can be determined by ensuring it remains coincident with that feature. However, determining where the bridge actually is along that feature is a bit more difficult. There are two possible methods.

Firstly, a distance, or chainage, from a known point could be used. Secondly, the bridge could be related to the intersection between the route and the feature that the bridge spans.

Feature Types:	Related Data Sets:	Relationship Types:
• Point	• Road Centreline	• Point Coincidence • Distance Along Line • Intersection

References:

- **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, November, 1995.

Rail Centrelines

Details: As with certain utility and other transport data sets, councils are not responsible for the positioning of railway lines. Rather this data set is used mainly for cartographic output. For council purposes only the relative position of the railway line with respect to the cadastre is necessary.		
Feature Types: • Lines	**Related Data Sets:** • Cadastre (present)	**Relationship Types:** • Relative Position • Bearing/Distance + others
References:		

Road Centrelines

Details:

Includes: Highways, Major Roads, Minor Roads, Tracks/Fire Trails, Gravel Roads, Private Roads, Cycleways, etc.

Councils are responsible the construction, maintenance and regulation of many of the public roads within their areas of control. The positions of the centrelines of these roads are a very useful piece of spatial information. Firstly, a number of other data sets used by councils are related to these centrelines (eg. Routes, Suburb Boundaries). Secondly, they can be used in maintenance program for the road itself.

Road Centrelines are actually related to another data set. They are not coincident with the road corridor (see Road and Rail Corridors) nor are they related to the cadastre in any other way. However it may actually be useful for council to relate these two data sets via a Bearing and Distance type relationship.

Whilst a road centreline is not technically related to any other data set, it may be related to another road centreline data set. This will occur in cases where different data sets are maintained for different road types. It is necessary to ensure in these cases, that the intersection points of the roads represented in each data set remains coincident.

Feature Types:	Related Data Sets:	Relationship Types:
• Lines	• Cadastre (present) • Road Centrelines	• Bearing and Distance • Relative Position • Point Coincidence

References:

- **White S., 1993,** Local Government Law and Practice: New South Wales, Volume 1, The Law Book Company, Sydney.

Road Pavement

Details:		
An increasing number of councils are using Road (or Pavement) Management Systems (PMS) in order to assist in the maintenance of roads under their control. In general, each section of a particular road is represented by a polygon against which information about the pavement type, traffic usage, date of construction, etc. are stored. This information is then used in the creation and monitoring of maintenance schedules. The polygons used to represent each road section can be related to either the road centreline (by offset) or to the road corridor.		
Feature Types: • Polygons	**Related Data Sets:** • Road Centrelines • Road Corridor	**Relationship Types:** • Offset • Line Coincidence

References:

- **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, November, 1995.
- **Batley K., 1997,** Personal Communication with Mr Kim Batley, GIS Coordinator, Liverpool City Council, March, 1997.

Routes

Details:

The provision of public transport services and the collection of garbage are both responsibilities of many councils. For various reasons, it is necessary for councils to know where these routes go. In the case of a bus route, it is important to ensure that the route serves an appropriate proportion of the population whilst minimising travelling times for users of the service. For garbage routes, however, a number of councils find it necessary to know how long a particular route is in order to monitor certain garbage contractors.

Obviously, routes such as bus and garbage routes will be completely coincident with road centrelines. Other routes, however will usually be coincident with some other feature.

Feature Types:	Related Data sets:	Relationship Types:
• Lines	• Road Centreline	• Line Coincidence

References:

Utilities

Electricity Transmission Lines

Details:

In general, councils are not responsible for the positioning of electricity transmission lines. This responsibility falls to other bodies. However, knowledge of the positions of these features can be invaluable for planning purposes as well as to prevent accidents occurring. Whilst the positions of overhead powerlines are obvious, underground powerlines are somewhat less obvious, the risk of accidently digging them up is quite great if their position is not known.

For council purposes, the absolute position of powerlines is not particularly useful. Rather the position with respect to some nearby feature, the cadastre for example, is more appropriate.

Feature Types:	Related Data Sets:	Relationship Types:
• Lines	• Cadastre (present)	• Bearing/Distance • Relative Position

References:

- **Smith J., 1995,** Personal Communication with Ms. Judy Smith, Hastings Council, April, 1995.

Sewerage Reticulation Network

Details:

Includes: Gravity and Rising Mains, Fittings, Junctions, Overflows, Pumps, etc.

A number of councils, especially in rural areas, are responsible for the maintenance of sewerage networks. The positioning of these networks plays an important role in certain developments. Furthermore, network features are, in general, underground thus making their detection by simple site inspection difficult. It is thus important for councils to know where the features of a network are. There are a number of ways in which a sewerage network can be mapped.

In some cases plans for a sewerage network will be based upon engineering designs and Work As Executed (WAE) Plans. In these cases, relationships in the form of ties (bearing and distances) will usually have been measured between known features (manholes, junctions etc) and nearby features (eg. cadastral corners). Thus, quite definite relationships between the cadastre and the sewerage network exist.

In other cases, however, only schematic information about the position of the network is available. In these cases only a relative position between the network and the cadastre can be used to relate the two.

In some councils, the sewerage network data set is split into a number of separate sets. It is necessary that the information for each of these sets coincides with any associated set.

Feature Types:	Related Data Sets:	Relationship Types:
• Points • Lines	• Cadastre (present) • Sewerage Network	• Bearing and Distance or • Relative Position • Point Coincidence

References:

- **Lee P., 1995,** Personal Communication with Mr. Phillip Lee, Australian Water Technologies, November, 1995.

Stormwater Catchment Areas

Details:

This data set is quite similar to Water Catchment Areas except that it is based upon particular stormwater drainage networks. The data set is used to identify parcels which are serviced by a particular stormwater system.

In the case of Baulkham Hills Shire Council, each Stormwater Catchment Area is created by picking all parcels of land serviced by a particular drain system.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (past)	• Line Coincidence

References:

- **Premalal., 1995,** Personal Communication with Mr. Premalal, Baulkham Hills Shire Council, September, 1995.

Stormwater Drainage Network

Details: Includes: Pipes, Pits, Manholes, etc. Similar to Sewerage and Water Reticulation Networks, it is necessary for councils to have knowledge of where particular features of the stormwater network are. See Sewerage Network.		
Feature Types: • Points • Lines	**Related Data Sets:** • Cadastre (present)	**Relationship Types:** • Bearing/Distance • Relative Position
References:		

Public Phones

Details:		
This is not a particularly common data set. It basically consists of the positions of Public Phone boxes with respect to the cadastre. Council use this information to examine the density of Public Phone boxes within certain areas of the community.		
Feature Types: • Points	**Related Data Sets:** • Cadastre (present)	**Relationship Types:** • Relative Position
References: • **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, November, 1995.		

Telephone Lines

Details: Similar to Electricity Transmission Lines, Telephone Lines are not the responsibility of Councils. However, once again, it is quite important for councils to know where these lines are for planning purposes and to prevent them from being disturbed by council earthworks.		
Feature Types: • Lines	**Related Data Sets:** • Cadastre (present)	**Relationship Types:** • Bearing/Distance • Relative Position
References:		

Water Reticulation Network

<table>
<tr><td colspan="3">Details:
Includes: Pipes, Hydrants, Fittings, etc.

Similar to Sewerage and Stormwater Drainage Networks. Councils need to have knowledge of where particular features in the Water Reticulation Network are in order to carry out maintenance upon them and for planning purposes. See Sewerage Networks.</td></tr>
<tr><td>Feature Types:
• Points
• Lines</td><td>Related Data Sets:
• Cadastre (present)</td><td>Relationship Types:
• Bearing/Distance
• Relative Position</td></tr>
<tr><td colspan="3">References:
• Lee P., 1995, Personal Communication with Mr. Phillip Lee, Australian Water Technologies, November, 1995.</td></tr>
</table>

Survey

Aerial Photography

Details:

Some councils are begining to use Orthophotography and similar products as a backdrop for vector information. A number of these councils have also recognised that the information in these images has other uses as well.

In general councils have attempted to register their photography to either Survey Control or, in some cases, the Cadastre. However at least one inner city council has expressed an interest in adjusting its vector data sets to fit aerial photography. Whatever the outcome, it is not possible to permanently relate these data sets due to the nature of image data.

Feature Types:	Related Data Sets:	Relationship Types:
• Image	None	None

References:

Map Grids

Details:
A number of councils use map grid data sets for cartographic output. These grids might represent mapping coordinates (eg. ISG or AMG) or they may act as an index to other map sheets.

Feature Types:	Related Data Sets:	Relationship Types:
• Lines	None	None

References:

- **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, November, 1995.

Survey Control

Details:

Survey Control information generally consists of point data only. These points have known coordinates with respect to some survey datum. Councils use this information as a register of bench marks (for engineering purposes) or as control for adjusting aerial photography, etc. They are not related to anything other than the survey datum.

Feature Types:	Related Data Sets:	Relationship Types:
• Points	None	None

References:

- **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, November, 1995.

Other

Animals

Details:		
Another responsibility of councils is to regulate the keeping of certain types of pets in their areas (eg. dogs). A number of councils have suggested that a spatially based, animal data set would be useful for carrying out this responsibility. Such information could be used to determine animal movement patterns and to trace the owners of strayed pets.		
Feature Types: • Point or • Polygon	**Related Data Sets:** • Cadastre (present)	**Relationship Types:** • Relative Position or • Coincidence
References:		

Contours

<table>
<tr><td colspan="3">Details:
Contour information is used by a number councils for a number of different purposes. These include; the determination of flood zones, the creation of Local Environment Plans, the determination of slope and aspect information (used in determining fire risk, amongst other things), and many other engineering and planning functions.

Contours are used to indicate height information about the land. This information is generally created from a Digital Elevation Model (DEM). It is not dependant upon any other data sets maintained by councils.</td></tr>
<tr><td>Feature Types:
• Lines</td><td>Related Data Sets:
None</td><td>Relationship Types:
None</td></tr>
<tr><td colspan="3">References:</td></tr>
</table>

Heritage/Aboriginal Sites

Details:

In order to make certain planning decisions and to make decisions about proposed developments, it is necessary for councils to know exactly what is on a particular parcel of land. This is because the site may actually contain an item of some cultural significance (eg. a heritage listed building or evidence of Aboriginal occupation). The existence of such an item may affect greatly any proposed development for the site.

There are two methods used for representing such features. Some councils capture the polygon containing the feature and use this to represent it whilst others simply use point features. In both cases the data set will be very closely related to the existing cadastre.

Feature Types:	Related Data Sets:	Relationship Types:
• Points or • Polygons	• Cadastre (present)	• Line Coincidence or • Relative Position

References:

- **Zouain S., 1995,** Personal Communication with Ms. Suzy Zouain, Canterbury City Council, September, 1995.
- **Leggatt G., 1995,** Personal Communication with Mr Geoff Leggatt, Hornsby Shire Council, October 1995.

Land Use

Details:

Includes: Land Fills, Schools, Car Parks, etc.

The knowledge of what a particular piece of land is being used for is very important to councils. This information is used in the creation of Local Environment Plans as well as other planning purposes.

As with many other data sets, this Land Use information is generally compiled with respect to the cadastre.

Feature Types:	Related Data Sets:	Relationship Types:
• Polygons	• Cadastre (present)	• Line Coincidence

References:

- **Fraser B., 1995,** Personal Communication with Mr Bruce Fraser, Senior Surveyor, Albury City Council, November, 1995.

Paracentroids

Details:

Paracentroids are not a data set as such. Rather, they are a set of point features used to represent polygons features. For example, a number of councils, rather than attaching attributes to each polygon in the cadastral data set attach such information to a set of paracentroids. In order to determine which paracentroid belongs to which polygon, the two data sets are overlaid. This technique is not used greatly.

Obviously the position of the paracentroid is very much dependant upon the polygon. It must remain within the polygon.

Feature Types:	Related Data Sets:	Relationship Types:
• Points	Many	• Relative Position

References:

• **Lebens G., 1995,** Personal Communictaion with Mr. Gary Lebens, Ku-ring-gai Council, September, 1995.

Text

Details:

Many councils use text data sets for the creation of cartographic output. In fact many councils view their text data sets as being very important.

In many cases councils have more than one text data set. Each of these sets is used for the production of different maps.

The actual text in each text data set is generally related to another particular data set. For example the cadastral data set may have an associated text data set which is used to place DP and Lot Numbers as well as Street Names on a map. Thus there is a very definite relationship between each piece of text and the features in an associated data set. Unfortunately it is not a simple task to determine what these relationships are.

As well as the relationships between text data sets and other sets, it is quite often necessary to ensure that text in one text data set does not interfere with another text data set.

Relationships between features in text data sets are very complicated yet are viewed by councils as being very important.

Feature Types:	Related Data Sets:	Relationship Types:
• Points • Lines • Polygons	• many (including other Text)	• Other

References:

- **Smith J., 1995,** Personal Communication with Ms. Judy Smith, Hastings Council, April, 1995.

Sampling Sites

Details:
Includes: Water Sampling Sites, etc.

In some cases, councils find it necessary to take frequent samples of some particular aspect of the environment. An example of this is a council taking water samples from a water source to monitor the quality of that water. In order to determine exactly what the cause of disruptions to this quality might be, it is necessary to know where the sampling site was. This is done by plotting the site with respect to some datum.

Feature Types:	Related Data sets:	Relationship Types:
• Points	None	None

References:

- **Leggatt G., 1995,** Personal Communication with Mr Geoff Leggatt, Hornsby Shire Council, October, 1995.

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